Case Study

Industrial Machine Vision

Using Intel® FPGAs for Real-Time Image Processing in High-Performance Industrial Cameras

Intel® Arria® 10 and Intel® Cyclone® 10 FPGAs are selected by Hamamatsu for high-performance ORCA-Quest scientific camera and new X-ray food inspection system due to real-time image processing capabilities and high-bandwidth interfaces

At a glance:

- Learn how Hamamatsu is leading its industry as a manufacturer of photonics products used in industrial and scientific research applications
- Explore why Hamamatsu adopted Intel® FPGAs for the latest scientific and food inspection cameras
- Gain knowledge of Intel® FPGAs selected for custom image processing and high-bandwidth data transmission

HAMAMATSU

PHOTON IS OUR BUSINESS

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The Age of Photonics

We are currently in the middle of a technological revolution. Industry 4.0 technologies including artificial intelligence (AI), edge-to-cloud, 5G, and the Internet of Things (IoT) are collectively generating enormous waves of data that require rigorous capturing, processing, and analysis. The field of photonics, in which researchers explore the properties and applications of light with a goal of transmitting information, provides a viable solution to handle such data requirements.

In fact, photonic devices are becoming ubiquitous due to their associated advantages over electronic counterparts in some instances. They are now critical in applications such as communications, medicine, astrophysics, and computing. More specifically, photonic components are found in fiber-optic communications, drug discovery, genetic analysis, and quantum computing.

"Every Photon Counts"

Hamamatsu Photonics, founded in 1953, is a leader in light-based technologies. Their products are prevalent in industrial and scientific applications for which performance, sensitivity, and accuracy are essential. Widely used Hamamatsu products include photomultiplier tubes, imaging devices, light sources, opto-semiconductors, imaging systems, and analyzing systems.

Recently, they demonstrated the successful capture of ultra-low light measurements, which are particularly challenging from an engineering perspective. Although there are scientific applications for which every photon counts, most conventional electronic devices do not support a seamless interaction between photons captured and sensors used for detection. Hamamatsu solved this issue with their newest ORCA-Quest camera.

As Hamamatsu developed the ORCA-Quest scientific camera along with a new X-ray food inspection camera, they worked to meet high-performance, low-cost requirements. Hamamatsu's cameras demanded extensive digital signal processing (DSP) that could be implemented with conventional processors. Additionally, these cameras required remarkably high bandwidth to handle the substantial data generated by sensors.

Hamamatsu turned to Intel® FPGAs for a unique solution that offered several advantages: 1) Intel FPGAs consisted of rich DSP resources capable of performance that was orders of magnitude higher than software-based processors. 2) Intel FPGAs also had flexible and configurable banks of multi-gigabit transceiver I/O to meet

extreme bandwidth demands. 3) The flexibility of the FPGA logic fabric enabled integration of many system functions into a single device, which reduced cost, printed circuit board (PCB) space, and power consumption.

ORCA-Quest Scientific Camera

Scientific cameras meet the ultra-low noise, high-sensitivity requirements of physics and life science applications. They are often used in quantum computing, astronomical imaging, cell imaging, and drug discovery applications. Hamamatsu used 30 years of research experience to develop the new ORCA-Quest qCMOS scientific camera. This camera is the first to realize photon number resolving, which counts the photoelectrons present at each pixel. Since photon number resolving is heavily affected by noise performance, Hamamatsu worked to attain an ultra-low readout noise of 0.27 electrons rms.

In addition to excellent low-noise performance and quantitative measurement capability, the ORCA-Quest qCMOS has the following features:

- High quantum efficiency (90% at 475 nm)
- High resolution (9.4 megapixels)
- High-speed frame rate (120 fps)

In the ORCA-Quest system, Intel FPGAs perform unique image processing to correct pixel variations within the sensors and to convert output data in terms of photoelectrons to photons at each pixel. Note that the image sensors generate data at a rate of over 18 Gbps while requiring processing and transmission in real time with minimum latency.

ORCA-Quest with Intel® Arria® 10 GX FPGA

Specification	
Number of effective pixels	4096 x 2304
Frame Rate	120 fps
Bit accuracy	16 bit (Monochrome)
Data Rate	18 Gbps

✓ **Implemented image processing to maximize sensor performance**
- Utilization of rich DSP, memory resources, and HW memory controller
- Image processing of 18 Gbps data in real time

✓ **Sensor control and data acquisition**
- Utilize flexible configurable I/O banks and LVDS SERDES IP cores from Intel

✓ **Transfer data using the CoaXPress interface**
- Utilize transceiver I/O (6.25 Gbps x4)

✓ **Utilization of firmware**
- Take advantage of Nios II to control logic

Choose the Intel Arria 10 GX that strikes a balance between cost and performance

The combination of high-performance Hamamatsu sensor and the high-speed processing available from the Intel® Arria® 10 GX FPGA allows the ORCA-Quest to realize both ultra-low noise performance and photon number resolving.

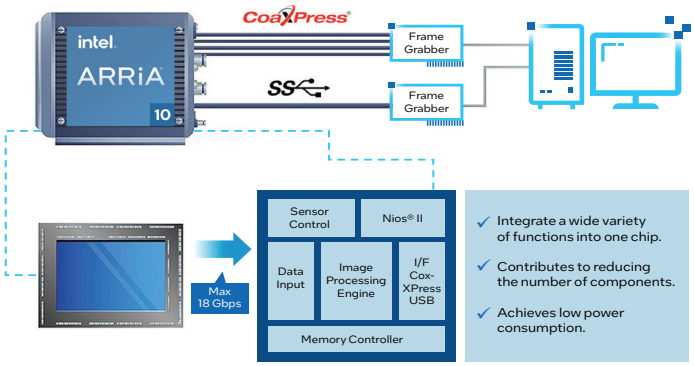


Figure 1. FPGA Architecture

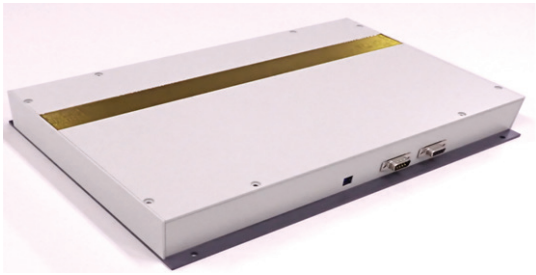
X-ray Food Inspection Camera

Hamamatsu's new X-ray food inspection camera also takes advantage of Intel FPGA technology. Food inspection cameras are typically used to detect foreign matter like metal, glass, and plastic within food containers. They are also used during quality inspection to confirm whether any part of food packaging is damaged, cracked, or chipped.

Typically, food inspection is performed using either an expensive dedicated machine that inspects low-contrast objects of certain thicknesses or using a less costly repurposed X-ray machine. Hamamatsu developed a new machine that combines the best attributes of these two choices, resulting in competitive cost, size, performance, and lifecycle.

To achieve a cost-performance balance and meet target specifications, Hamamatsu combined Intel® Arria® 10 GX and Intel® Cyclone® 10 FPGAs within their food inspection system. Their main priority was controlling multiple sensors during data acquisition, so many configurable I/O banks were necessary. To maximize performance, they sought to process images very closely to the sensor in the signal chain.

Hamamatsu leveraged the rich Intel FPGA IP portfolio, which includes memory controllers, interconnect IP, and Nios® soft-core 32-bit processors. Product lifecycle considerations were weighed in, as well, due to the long lifecycle of the end product.



FPGAs Meeting Photonics Demands

Modern technologies are rapidly changing our society as they directly and indirectly touch the lives of almost everyone on the planet. Global demands for increased performance require engineering teams to future-proof designs, enabling scalability and flexibility in the field.

Particularly in the field of photonics, extreme performance is necessary for complex signal processing. Achieving this performance while maintaining flexibility and rapid time to market is an excellent fit for Intel FPGA technologies since FPGAs deliver rich custom logic resources, configurable high-performance I/O, and in-system reconfigurability.

Long-term Relationship

Hamamatsu builds products to withstand the harsh environments associated with field research, manufacturing, and other similar use cases. During product development, the company often works with trusted partners like Intel and Macnica. Hamamatsu is a longtime Intel FPGA user given Intel's history of producing high-quality FPGAs with long lifecycles. Hamamatsu strongly trusts Macnica as a key partner providing high-touch technical and commercial support.

For More Information

Visit the following pages to find more detailed information about Intel products and solutions:

- Machine Vision FPGA Computer Vision - Intel® FPGA
- Intel® FPGAs and Programmable Devices-Intel® FPGA
- Hamamatsu ORCA-Quest qCMOS Camera Brochure

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