Kria KR260 Robotics Starter Kit: Unleashing Roboticists through Hardware Acceleration

The Kria KR260 Robotics Starter Kit includes pre-built interfaces for robotics, machine vision, industrial communication and control applications, customizable hardware accelerated functions and enables faster time to deployment through Kria SOMs.

ABSTRACT

The Kria™ KR260 Robotics Starter Kit is a Kria SOM-based development platform for robotics and factory automation applications. It enables roboticists and industrial developers without FPGA expertise to develop hardware accelerated applications for robotics, machine vision, industrial communications and control. Developers benefit with greater flexibility from native ROS 2 (Humble Hawksbill release with Ubuntu 22.04 LTS) support and increased productivity through the Kria Robotics Stack (KRS). The pre-built interfaces and accelerated applications make the KR260 an ideal platform to accelerate robotics innovation and take those ideas to volume production deployment with the industrial-grade Kria K26 SOMs. The combination of the popular and rapidly growing ROS 2-centric environment, the unmatched low-latency and determinism of FPGA-based hardware acceleration for real-time performance and the architectural emphasis on safety and security bring the notion of adaptive computing to the forefront of embedded options for roboticists and industrial developers.

Introduction

This white paper builds on the concepts introduced in Xilinx white paper WP537, *Adaptive Computing in Robotics* and WP540, *Kria™ Robotics Stack*, and for those new to the concept of Kria System-on-Modules (SOMs), the motivation behind Kria SOMs is covered in WP528, *Achieving Embedded Design Simplicity with Kria SOMs*.

Robotics, and the class of products that help achieve higher levels of industrial automation, are increasingly important to everyday lives today and into the future. Just as the pandemic of 2020 and 2021 have dramatically altered how, where, and when billions of people work, the aftermath of the pandemic has created a shift in thinking around what people work on. As a result, there is a global worker shortage from factories to farms, but the restart of the worldwide economy has created an increased demand across the spectrum of raw materials, components, and finished goods alike.

Higher levels of automation, including the use of robotics, advanced machine vision, with real-time networks to connect the web of sensors, drives, controllers, with local industrial PC and cloud-based management systems have been talked about since the arrival of the Industrial Internet of Things (IIoT) revolution a decade ago. In many ways, it seems the last decade has been spent exploring and trialing what is possible while driven by the motivation of productivity gains. By contrast to today, for the first time, the world is called to put these technological pieces and prototypes into practice, relying heavily upon them without a firm safety net, to put food on tables, transport people and goods, and move the world forward after a period of disruptive pause. To reflect this intuition about growing global demand for automation, Omdia shows robotics growing at an accelerated compound annual growth rate (CAGR) of 20.4% between 2019 (pre-pandemic) and 2025 as shown in Figure 1, illustrating an world markets increase of almost 85 billion dollars in six years.

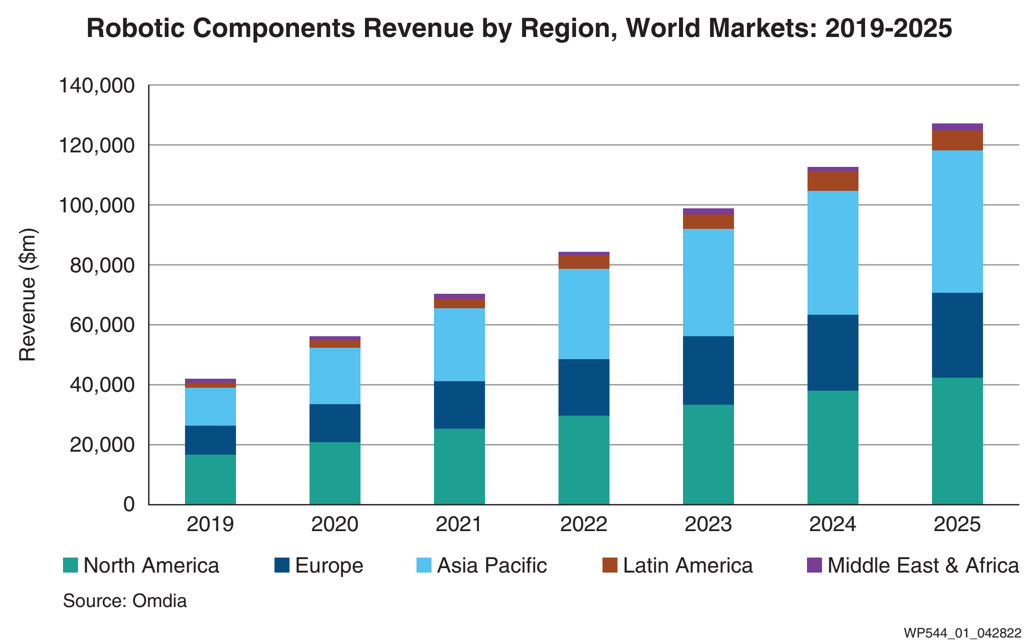

Figure 1: **Growth Projections for Robotic Components by Region of Deployment, Omdia 2020**

Much of this growth will be due to demand from small and medium enterprises in manufacturing, warehouse/logistics, food/beverage, agriculture, construction, and aerial robots deployed in Asia Pacific, North America, and Europe as well as expectations of strong growth in the number and types of emerging applications during the forecast period. The strong CAGR is consistent with a market that has momentum and sustained demand.

Most Accessible Form of Adaptive Computing

As explored in detail in WP537, adaptive computing, and particularly Kria SOMs as the most accessible form of adaptive computing, are the perfect compute platform for robotics. Adaptive computing simplifies system integration, meets compute power density requirements, and adapts to the changing demands of robotic applications with high reliability, performance, and precision.

The Kria KR260 Robotics Starter Kit, shown in Figure 2, is the easiest way to develop ROS 2-based robotics with the attributes of adaptive computing, as well as in adjunct applications involving industrial vision and communications and control.

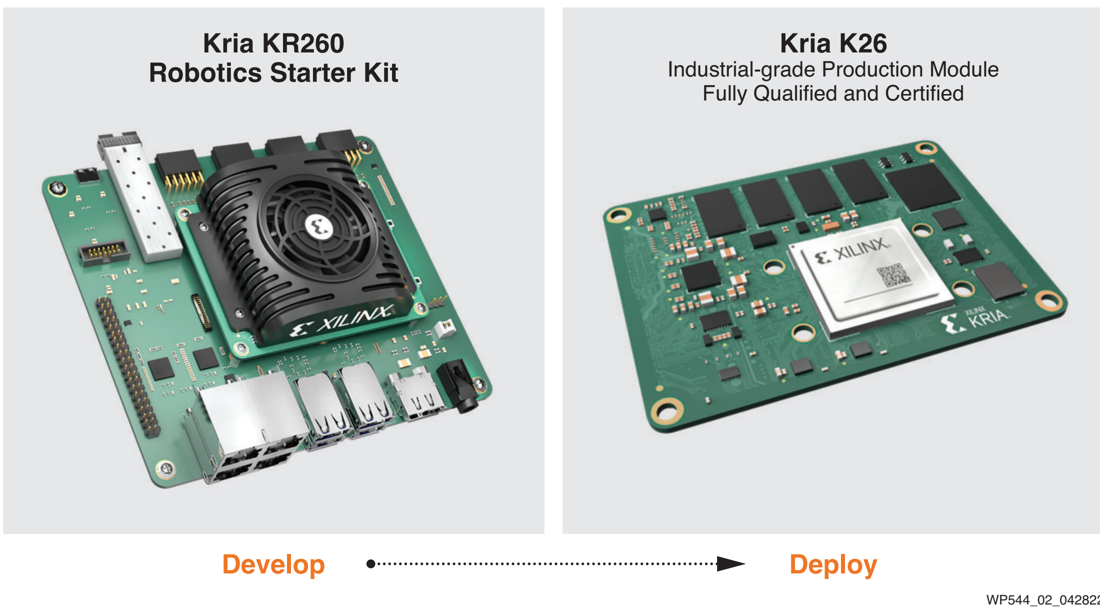

Figure 2: **Kria KR260 Robotics Starter Kit and the Credit Card Sized K26 SOM**

The KR260 follows the concept of all Kria starter kits as an out-of-the box ready solution with no proprietary tools or deep hardware experience or specialized software expertise to operate it. Developers can be up and running in under one hour by launching an accelerated application, such as the ROS 2 Perception Node application, from the Xilinx App Store. They immediately obtain the underlying benefits of FPGAs (flexibility with real-time performance enabled by hardware acceleration) tightly coupled with an Arm® processor subsystem and flexible peripheral set in one adaptive system-on-chip (SoC), which is delivered with components such as memories, power management, and baseboard expansion connectors in the form of a Kria SOM. The KR260 pairs a non-production Kria K26 SOM with a mating baseboard that contains connections that are critical for robotics and factory automation design and development. This provides developers the ability to start with an easy foundation and build upon it using design flows (ROS 2, C++, Python, FPGA RTL, etc.) best suited to their skill set. Finally, the KR260 developers get access to the ecosystem and resources needed to ultimately develop their own baseboard for full volume production with Kria SOMs.

This white paper takes a closer look at the key features and value propositions of Xilinx's latest Starter Kit offering in the Kria SOM portfolio.

Key Issues in the Robotics Market

The primary issue with robotics design is consistent with the broader challenges in factory automation component design, but more acute. With the IIoT revolution and the resultant Information Technology-Operational Technology (IT-OT) convergence that ensued, there quickly emerged a rather lengthy list of required IIoT technologies: cybersecurity, functional safety, industrial Ethernet, embedded vision, multi-axis control, and software and operating systems that can support mixed criticality and machine learning-based AI. As Xilinx white paper WP493, Key Attributes of an Intelligent IIoT Edge Platform highlights, developers need to position these technologies at the analog-digital boundary (the IIoT edge) for maximum efficiency, performance, and privacy. They also need to create platforms built from adaptive components to save development time in these systems and extend the life of these systems after they are deployed.

Taking a step back and looking from a higher level of abstraction, a robot can be viewed as a system of systems and robotics, the art of integration of these systems into a well coordinated ensemble.

The Essentials of Robotics

The essential characteristics and functional blocks of robotics systems can be summarized by a few properties:

1. Sensing and perception by mean of multitude of sensors like vision, audio, thermal, radar, LiDAR, and others provide the information of the environment.
2. Optimal processing of the information at the edge or cloud as it maximizes some cost criteria.
3. Forecasting plans ahead of needs.
4. Decision and control that actuate sensing and planning.
5. Communication that provides timely and highly available information to single and multiple robots geographically distributed.
6. Mobility, allowing the robot to move in the environment with autonomy.

As systems are added to fulfill these properties, complexity rises and the challenge of system integration can grow exponentially.

Handling the Complexity

To handle the complexity, a good strategy is to start at the most atomic level, with an adaptive canvas, which allows placement of the proper function at the proper level. This is similar to when an artist selects the most suitable color for a very particular area of their painting. Xilinx offers many adaptive SoCs with industrial and healthcare IoT solutions, but the significance of the KR260 Starter

Kit is that it is the first time Kria SOMs, Kria accelerated applications, and the Kria Robotics Stack (KRS) are combined to offer an adaptive computing-based, ROS 2-friendly enhanced starting point for developers seeking to scale their robotic development efforts into multiple iterations and applications easier than ever before.

KR260 Robotics Starter Kit Hardware

As depicted in Figure 3, the KR260 Starter Kit simplifies the system integration of hardware accelerated ROS 2 for Robotics, SLVS-EC vision sensors, and industrial interfaces like 10 GigE Vision, EtherCAT, and time sensitive networking (TSN), among others, to speed development of the adaptable, intelligent factory. The KR260 Starter Kit features a non-production K26 SOM with both 240-pin connectors populated to provide ample I/O to support for following interfaces and more:

- 4x RJ-45 Ethernet ports (2x PS for standard Ethernet, 2x PL to enable industrial Ethernet) and 1 SFP+ cage for 10GigE Vision to network interface cards connectivity
- 2-lane SLVS-EC RX interface (up to 12.5G) via FRAMOS Hirose connector for high-performance industrial vision sensors such as the Sony IMX547 global shutter 5.1MP/10-bit/122fps sensor
- 4x USB3.0 interfaces to connect additional camera or peripherals like a keyboard and mouse to use the kit stand-alone with an Ubuntu desktop
- DisplayPort 1.2a 1080p interface to output data to a monitor
- Via 4x Pmod (2x6) interfaces and Raspberry Pi headers, developers can plug virtually any sensor or interface of their choice and leverage the broad Pmod and Raspberry Pi ecosystems (including Wi-Fi, Bluetooth, and RS-485 modules) for their target application

For full details of the KR260 and Kria SOMs, refer to the website:
https://www.xilinx.com/applications/industrial/robotics/kria-robotics.html

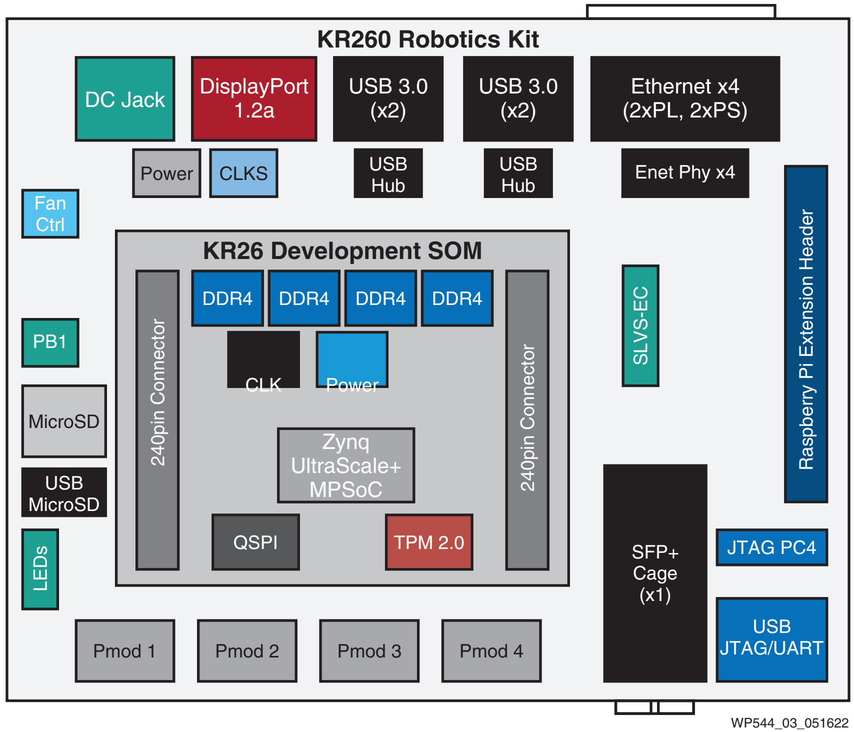

Figure 3: **KR260 Starter Kit Block Diagram**

Comparing KV260 and KR260 Starter Kits

While the Kria K26 SOM is integrated with both kits, the KV260 Vision AI Starter Kit for mainstream vision AI systems provides a complementary portfolio member to the KR260 Robotics Starter Kit for high-performance industrial systems. To see key differences highlighted, see Figure 4.

	KV260 Vision AI Starter Kit		KR260 Robotics Starter Kit
SOM I/O Access	1x 240-Pin Connector	▶ 2x SOM I/O ▶	2x 240-Pin Connector[1]
Network	1x Ethernet	▶ 4x Ethernet ▶	2x Industrial Ethernet, 2x Ethernet, SFP+
Vision	MIPI Vision Sensors	▶ SLVA-EC ▶	SLVS-EC Vision Sensors
Interface Expansion	1x Pmod	▶ 4x Pmod ▶	4x Pmod

1: All SOM I/O accessable to user, including dedicated board connectors (SFP, Ethernet, VLVS-EC headers) and I/O expanders (e.g., Pmods)

WP544_04_050922

Figure 4: **Comparing KV260 and KR260 Starter Kits**

Getting Started Experience: No FPGA Experience Required

Like the KV260 Vision AI Starter Kit, the KR260 Robotics Starter Kit is built to be developer-friendly, which is reflected in the getting started experience. No FPGA experience is required and Xilinx tools do need not be installed beforehand to begin exploring the kit's capabilities. Its ease of use allows all developers to experience the benefits of adaptive computing, regardless of their backgrounds. The recommended application to start with is the ROS 2 Perception Node accelerated application (Perception-ROS app) because it is representative of a ROS 2 package with a decent computationally intensive workload to appreciate the acceleration, and it does not require additional hardware other than a PC running the Gazebo simulator to generate camera data. This application can also use an external ROS-compatible camera if available as shown in Figure 5.

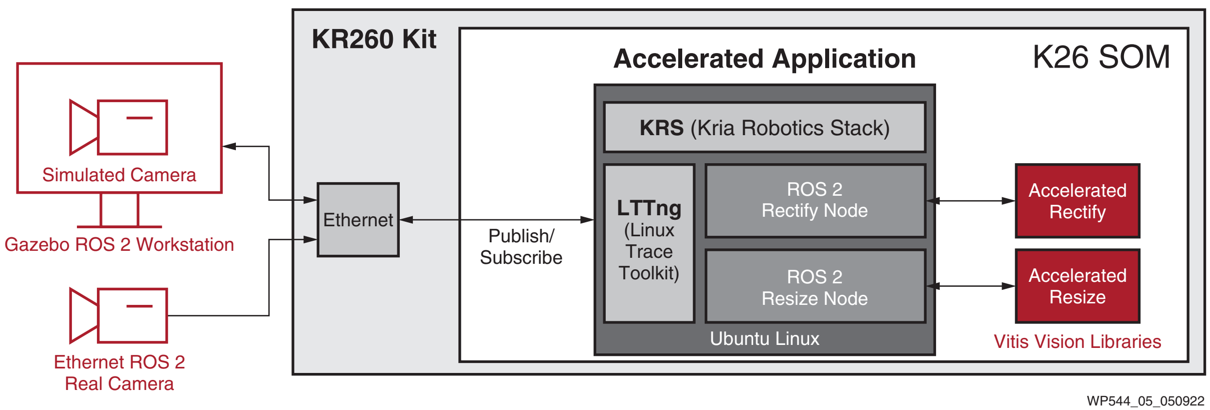

Figure 5: **Perception-ROS App**

To begin, developers can scan the QR code in the "Getting Started" document provided with the kit. They will be directed to the "Getting Started" webpage, which has clear instructions to get their design up and running by launching the Perception-ROS app for the very first time. The Perception-ROS app, like many of the other applications in the Xilinx App Store, can be modified and built upon by users. Additional resources like On-Demand training and forum support are available for deeper understanding and to help developers who need assistance along the way.

Enabling Developers in Their Familiar Environment

With Kria SOMs, different developer personas have a design path option created for them as specified in Figure 6. AI Developers can drop in their custom, trained AI model using Caffe, Tensorflow, Pytorch, or popular frameworks into the adaptive AI processor to meet their design requirements using Vitis™ AI development environment. Roboticists can also take advantage of KRS which allows them to build workspaces for Kria platforms using ROS 2. Embedded developers can develop with C++, OpenCL, Python and HW developers can use RTL to go further with higher levels of customization as needed by using Xilinx tools like Vitis and Vivado, respectively.

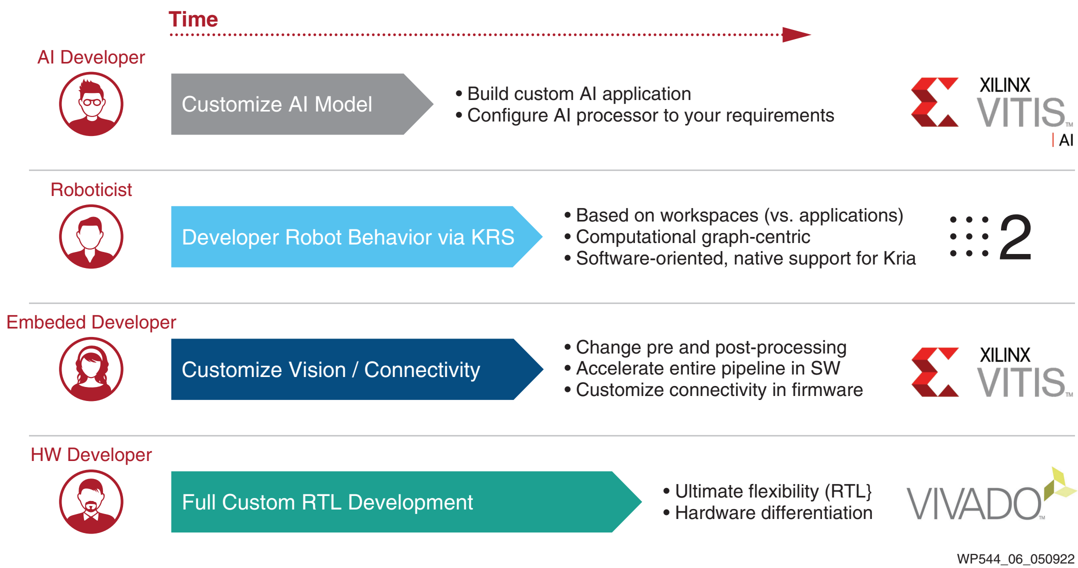

Figure 6: **Design Paths for Developers**

Native ROS 2 Support for Greater Productivity and Flexibility for Roboticists

As detailed in WP537, the Robot Operating System (ROS) is a set of open-source software libraries and tools for building robot applications. From drivers to algorithms and supported by powerful developer tools, ROS 2 is the de facto framework for robot application development. ROS 2 addresses the critical limitations of the original ROS and adds Data Distribution Service (DDS) as the communication middleware.

At the time of launch, the KR260 starter kit is compatible with the latest long-term support (LTS) versions of Ubuntu Linux Desktop (22.04) from Canonical and ROS 2 Humble Hawksbill, which is based on Ubuntu 22.04.

With both the KV260 Vision AI Starter Kit and the KR260 Robotics Starter Kit, Xilinx supports the Kria Robotics Stack (KRS) for Roboticists. As detailed in WP540, KRS is an integrated set of robot libraries and utilities that use hardware to accelerate the development, maintenance, and commercialization of industrial-grade robotic solutions. It adopts ROS 2 as the Software Development Kit (SDK) and proposes a ROS 2-centric development approach to enable a software-defined, hardware-accelerated platform. Refer to Figure 7 for a simplified view of KRS and how it encompasses a robust set of system layers to enable hardware accelerated libraries.

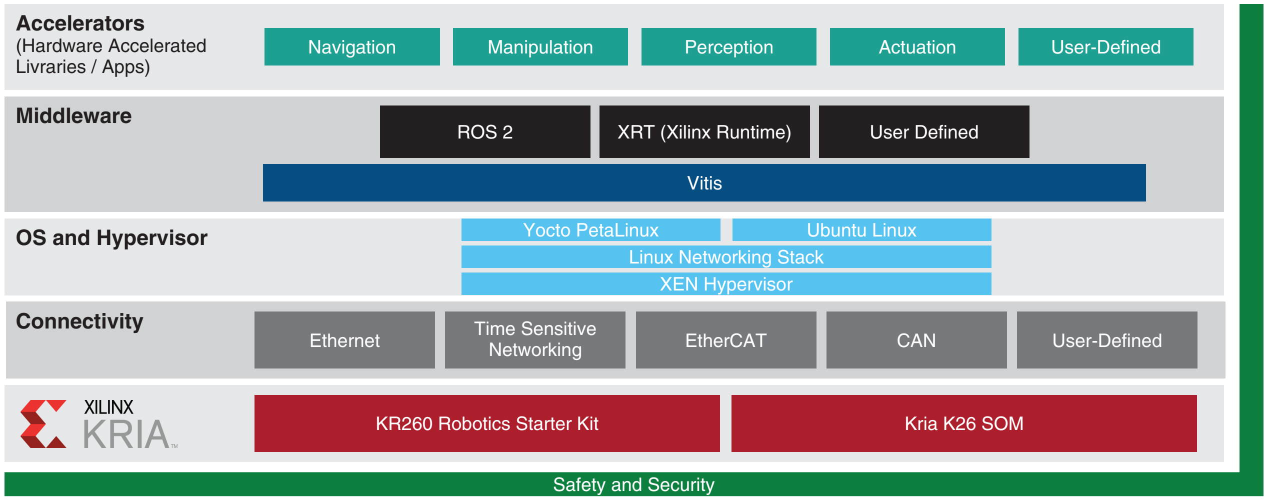

Figure 7: **Kria Robotics Stack (Simplified View)**

One of the key features of KRS is its optimization of the ROS 2 performance via FPGA-based hardware acceleration of some elements within the layers such as TSN connectivity or packages within the perception stack. KRS can also be used by developers who do not use ROS since most components are agnostic to the framework and can be used within traditional FPGA design approaches

For the roboticist, the ROS 2 build system (`ament`) and ROS 2 build tools (`colcon`) have been extended with layers that empower and facilitate hardware acceleration. The process of building acceleration kernels is thereby simplified and not different from building any ROS 2 package. With these significant productivity tools, any roboticists using ROS 2, is now able to build and quickly deploy hardware-accelerated functions.

5X Productivity and 3.5X Performance Advantage with the Kria Robotics Stack

Together, KRS and the KR260 Starter Kit enable an approximate 5X productivity boost during development at 3.5X lower latency over competing approaches.

As highlighted in Figure 8, users achieve a 4.7X reduction in the time it takes to build accelerated ROS 2 applications, without getting involved deeply with Xilinx proprietary tool flows like Vitis or Vivado tools. KRS offers increased productivity through the following areas of development:

1. Tool chain setup and integration
2. Computational graph development in ROS 2
3. ROS build system macros calling Vitis and Vivado tools in the background

Vitis tools are hidden from roboticists, who can focus on working within the computational graph workspace in ROS 2.

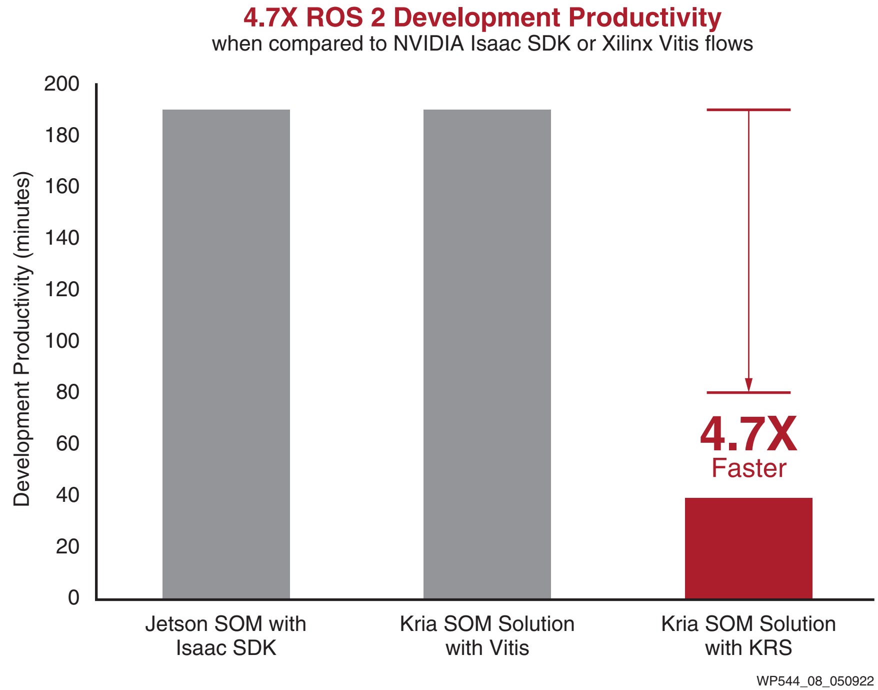

Figure 8: **Summarized Productivity Performance Advantages over Competition**

At runtime, using the Perception-ROS App as an example, users can expect up to 3.5X faster execution of common functions in the ROS 2 perception package. Figure 9 highlights internal benchmarks taken in April 2022 comparing full Kria K26 SOM performance relative to two other approaches: Nvidia Jetson Nano and Nvidia Xavier AGX. All benchmarks for the two GPU-based approaches were created using Nvidia Isaac SDK where the Kria SOM approaches were created using KRS. All benchmark measurements were created using LTTng (Linux Trace Toolkit: next generation) instrumenting the perception package at critical points such that measurements can be reproduced by any user in the future. The benchmarking results focus on the ROS 2 perception package > Image_pipeline > image_proc and specifically the functions rectify, resize.

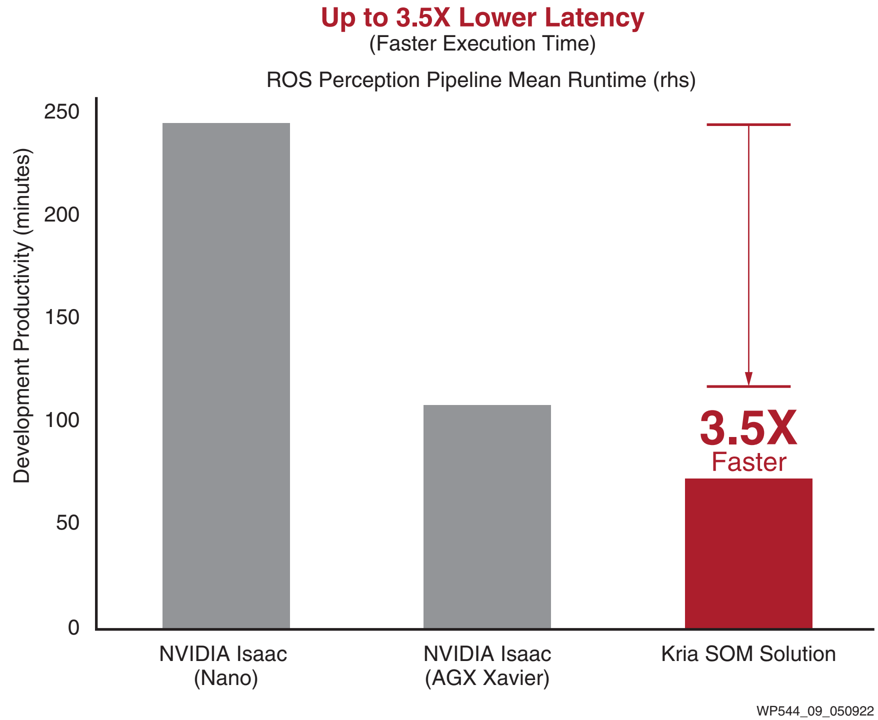

Figure 9: **Lower Latency with Kria SOM Solution**

Beside the self-evident speedup factor of the full Kria K26 SOM in all cases across all competitive scenarios, it is important to highlight two key attributes of adaptive technology. First, the relative speed-up increases linearly with the number of accelerated nodes, so the greater the complexity of design, the larger the advantages of adaptive technology. The design used in this benchmark is a trivial design, whereas a more real-world design could exceed 10X speedup over alternative approaches. Secondly, improvements and enhancements toward hardware acceleration of these packages can be enhanced and tuned over time. A fuller treatment of this benchmarking depicted in Figure 9 is available at https://github.com/ros-acceleration/community/issues/20#issuecomment-1047570391

Additional Accelerated Applications for KR260

The concept of accelerated applications delivered via the Xilinx App Store has been critical in bringing the Xilinx benefits to new users without FPGA design experience. Xilinx and ecosystem partners are building a growing list of accelerated applications—in a sense, production-grade reference designs. Each pre-built accelerated application transforms the K26 SOM into a 10 GigE Vision camera, or a ROS 2 TSN communications node, or a ROS 2 perception node, etc. Each application leverages the same robust K26 hardware as its computing engine, but each one deploys different hardware accelerators that are purpose-built specifically for targeting its end application. Here is a summary of the accelerated applications available for the KR260 Starter Kit at time of launch:

- ROS 2 Perception Node: This application enables high-performance robotic perception through hardware acceleration of components of ROS 2 perception stacks, enables Gazebo simulation flows, and is a pathway to future design with KRS.

- ROS 2 Multi-Node Communications via TSN: Creates a ROS 2 DDS publisher-subscriber node using TSN MAC-layer communication over Ethernet connection. See Figure 10.

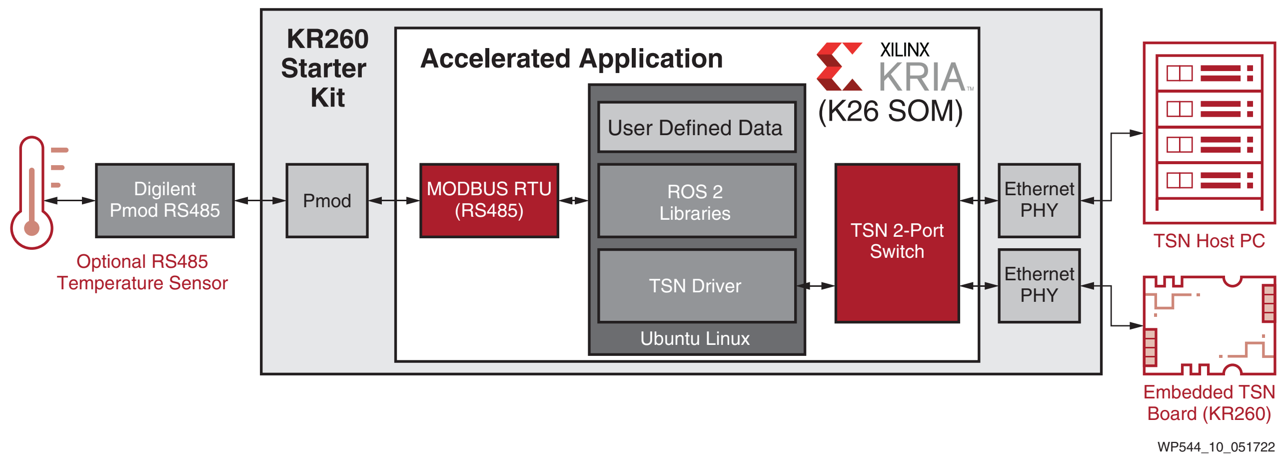

Figure 10: **ROS 2 Multi-Node Communications via TSN**

- 10GigE Vision Camera: Two applications in one-factory automation camera using SLVS-EC sensor input and GigE Vision camera to PC output with an additional embedded vision camera branch directly to monitor showcasing embedded defect detection OpenCV algorithms. The compatible Sony IMX547 monochrome or color image sensor is available as an accessory for an additional charge. See Figure 11.

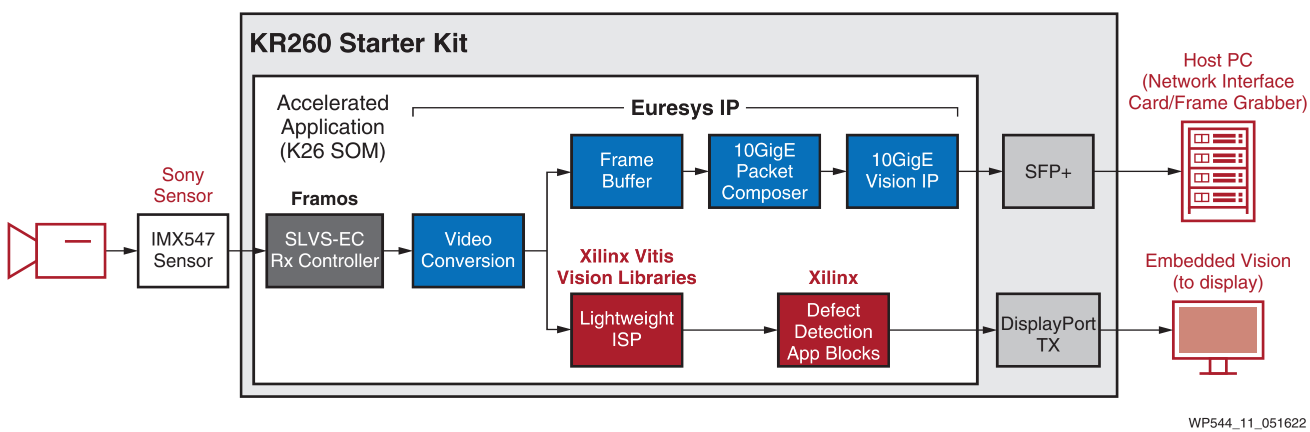

Figure 11: **10GigE Vision Camera**

Visit the Xilinx App Store for more details about the Kria accelerated application - https://www.xilinx.com/products/app-store/kria.html

Conclusion

The Kria KR260 Robotics Starter Kit is an excellent development platform for both entry-level and experienced roboticists looking to create innovative ideas for ROS 2-based robotics and take them to production. This starter kit features key interfaces for developing applications for robotics, machine vision, and industrial communications and control. Accelerated applications available on the Xilinx App Store and the Kria Robotics Stack (KRS) make the starter kit an out-of-the box ready platform. The seamless path to production deployment through Kria SOMs helps developers, especially in small and medium enterprises, get to market faster, reduce total cost of ownership, and access the underlying FPGA benefits of low latency and determinism through Xilinx adaptive SoCs.

Visit the Kria KR260 Robotics Starter Kit product page to learn more at www.xilinx.com/kr260 and join the ROS 2 Hardware Acceleration Working Group (HAWG) to connect with a community of developers that believe in the potential of software-accelerated hardware for embedded systems at https://discourse.ros.org/t/proposal-for-ros-2-hardware-acceleration-working-group-hawg/20112

Acknowledgment

The following AMD employees have authored or contributed to this white paper:

Karan Kantharia, Product Line Manager–Kits

Chetan Khona, Sr. Director, Industrial, Vision, Healthcare & Sciences

Revision History

The following table shows the revision history for this document:

Date	Version	Description of Revisions
05/17/2022	1.0.1	Typographical edit.
05/17/2022	1.0	Initial Xilinx release.

Please Read: Important Legal Notices

Automotive Applications Disclaimer