Technical White Paper

General Purpose processors for high compute, HMI, and connectivity applications

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ABSTRACT

General-Purpose ARM-based processors have emerged as versatile and indispensable components across a wide range of applications and industries. Renowned for their energy efficiency, scalability, and performance, ARM-based processors are at the forefront of modern computing. These processors are the driving force behind countless devices and systems from Human Machine Interface (HMI) to factory automation Programmable Logic Controllers (PLC). Widespread adoption of these can be attributed to their adaptability, enabling manufacturers and developers to create efficient solutions tailored for specific needs.

In this paper, we explore the key attributes and applications of TI's latest family of ARM-based processors and shed light on their significance in technology landscapes.

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1 Introduction

The global market for 64-bit processors in Industrial/Medical Sector was valued at $4.3 billion in 2023 and is expected to grow at a CAGR of 5.9% (Compounded Annual Growth Rate)[1]. As Industrial markets continue to develop and integrate, the technical requirements continue to as well. Low end processors are now being swapped out for higher end processors capable of computing Millions of Instructions per second (MIPS) through powerful ARM cores. Older data interfaces are now being upgraded to support bandwidth of Gigabits per second over multiple instances. High end graphics is needed to bring visualizations to an operator of a machine. In sectors such as Factory Automation, Building Automation, and Networking, the requirements have grown to utilize these technical aspects of a processor. Processors are becoming ubiquitous, with their presence nearly everywhere we turn.

TI's Embedded processors (EP) are able to meet the requirements above and accelerate this trend into new markets. EP, through multiple ARM cores, are able to meet the new demand for more computing power. EP, through Graphics Processing Unit (GPU), are able to meet the next level of visualizations that are needed to bring what a machine "sees and feels" to its operator. EP, through multiple high-speed interfaces, are able to address the bandwidth gap and connectivity requirements, ensuring that not just a product is connected but the whole building is in sync with itself. TI's General-Purpose processors are able to bridge the gap from 15 years ago to now!

This paper focuses on the highly-integrated AM6x processors and several use cases including Human Machine Interface (HMI), Programmable Logic Controllers (PLC), and Industrial PCs (IPC). Optimizing the systems using the heterogeneous architecture of the AM6x portfolio of devices with the easy-to-use software architecture is also discussed.

2 AM68 Processor

The AM68 is a dual-core Arm® Cortex® A72 microprocessor. The processor is designed as a high-performance and highly-integrated device providing significant levels of processing power, connectivity and graphics capability. Compared with the AM62 [2], which is designed for applications on the lower end of compute and display requirements, the AM68 achieves up to 25k Dhrystone Million Instructions Per Second (DMIPS) and allows up to 4K display resolution. The AM68x family is built for a broad set of cost-sensitive high-performance compute applications in Factory Automation, Building Automation, and other markets. Figure 2-1 shows the following multiple sub-systems based on the heterogeneous architecture of the AM68.

- A dual-core Arm Cortex A72 microprocessor at 2 GHz provides up to 25K. DMIPS.
- BXS-4-64 GPU offers up to 50 Giga Floating-point Operations per Second (GFLOPS) to enable dynamic 2D and 3D rendering for enhanced viewing applications.
- 1x 4L SERDES interface offers a combination of two of the three interfaces concurrently
  - 1x up to 4 lane PCIe Gen 3, up to 8(GT/s) per lane
  - 1x USB 3.0 dual-role device (DRD) subsystem
  - 1x up to 4 lane DisplayPort/eDP interface (up to 4k resolution)
- Display Sub-System (DSS) supports multiple displays with the flexibility to interface with different panel types such as eDP, DSI, and DPI.
- H.264, H.265 encoder and decoder can encode and decode multiple channels simultaneously. This encoder and decoder support H.264 Baseline, Main, High Profile at L5.2 and H.265 Main Profile at L5.1. The H.264, H.265 encoder and decoder can process 480 MP/s, for example, 8 channels of 2MP at 30 fps.
- 2x 4-lane MIPI CSI-2 RX are included in the AM68. Two high-resolution (for example, 12MP) cameras can be directly connected to CSI-2 RX ports.
- Gigabit ethernet capability with Two Ethernet RMII/RGMII interfaces
- Improved memory architecture and high-speed interfaces improve the system throughput by enabling high utilization of cores and HWAs. The AM68 supports up to 34 Giga Bytes Per Second (GBps) DDR memory bandwidth.

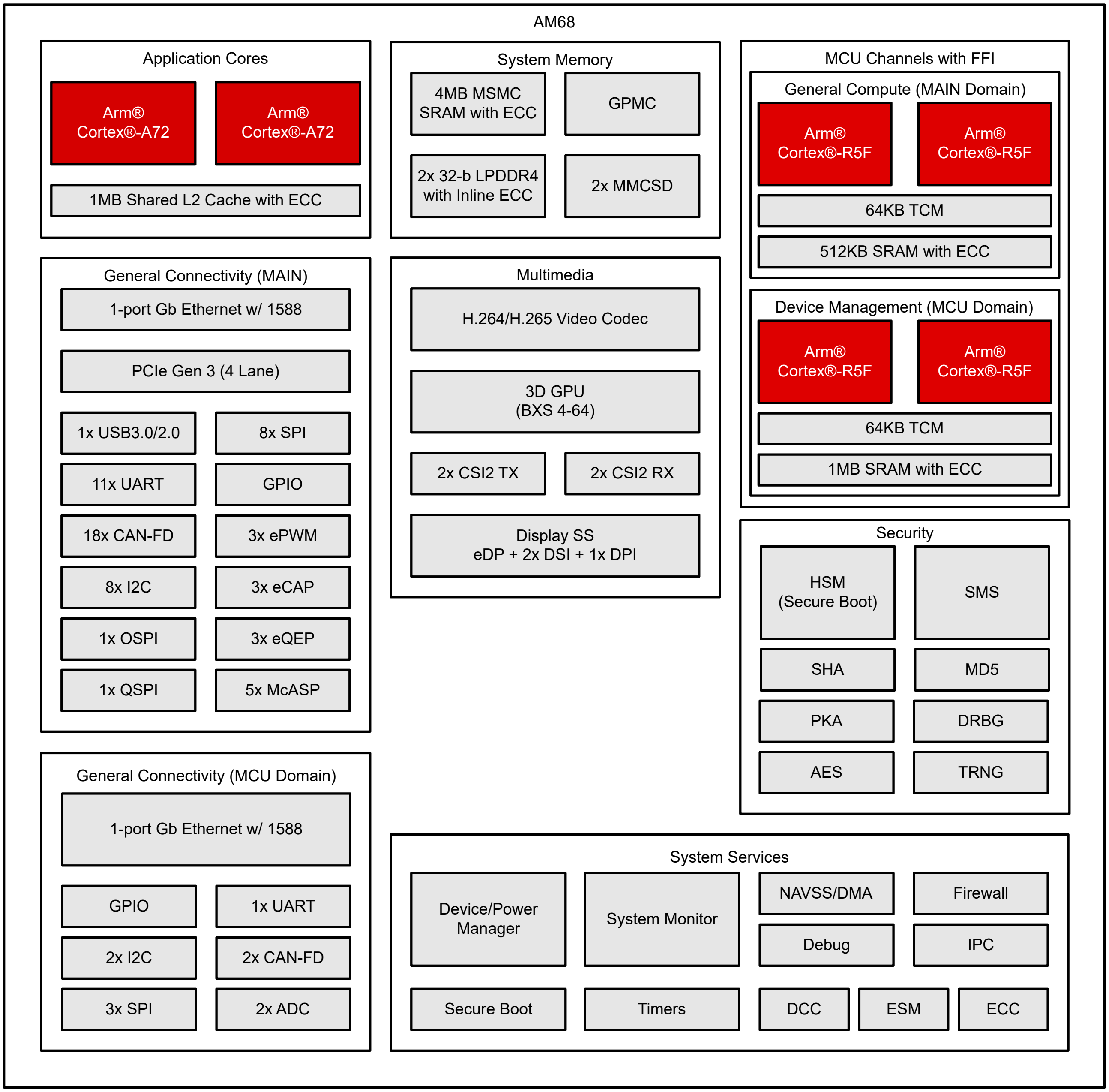

Figure 2-1. AM68 Block Diagram with Subsystems

3 AM69 Processor

The AM69 processor is the highest performance device among the AM6x scalable embedded processor family. Along with the octal-core Arm® Cortex® A72 microprocessor, the AM69 provides the most significant levels of processing power, image and video processing, and graphics capability. Compared with the AM62 (2) and the AM68, which are excellent choices for the applications with 1-4 A53 cores and 2 A72 cores, respectively, the AM69 enables the capability of up to 8 A72 cores to take your application to the next level of ARM computing with 100k DMIPS. As shown in Figure 3-1, the AM69 processor features the following multiple sub-systems based on the heterogeneous architecture:

- An octal-core(8x) Arm Cortex A72 microprocessor at 2 GHz provides up to 100k Dhrystone Million Instructions Per Second (DMIPS).
- BXS-4-64 GPU offers up to 50 Giga Floating-point Operations per Second (GFLOPS) to enable dynamic 2D and 3D rendering for enhanced viewing applications.
- 4x 4L SERDES interface offers a combination many high-speed interfaces
  - 2x 4L PCIe Gen 3 OR up to 4x 2L PCIe Gen 3 (up to 8(GT/s) per lane)
  - 8x SGMII ethernet ports (TSN) with eight port
    - All ports support 1Gb, 2.5Gb SGMII
    - Two ports support 5Gb, 10Gb USXGMII or 5Gb XFI
  - 1x USB 3.0 dual-role device (DRD) subsystem
  - 1x up to 4 lane DisplayPort/eDP interface (up to 4k resolution)
- Display Sub-System (DSS) supports multiple displays with the flexibility to interface with different panel types such as e/DP, DSI, and DPI.
- 2x encoder and decoder with H.264, H.265 support can encode and decode multiple channels simultaneously. This encoder and decoder support H.264 Baseline, Main, High Profile at L5.2 and H.265 Main Profile at L5.1. The 2x CODEC can process 480 MP/s each module at 4K60 throughput.
- 3x 4-lane MIPI CIS-2 RX are included in the AM68. Three high-resolution (for example, 12MP) cameras can be directly connected to CSI-2 RX ports.
- Improved memory architecture and high-speed interfaces improve the system throughput and energy efficiency by enabling high utilization of cores and HWAs. AM69 supports up to 64 Giga Bytes Per Second (GBps) DDR memory bandwidth.

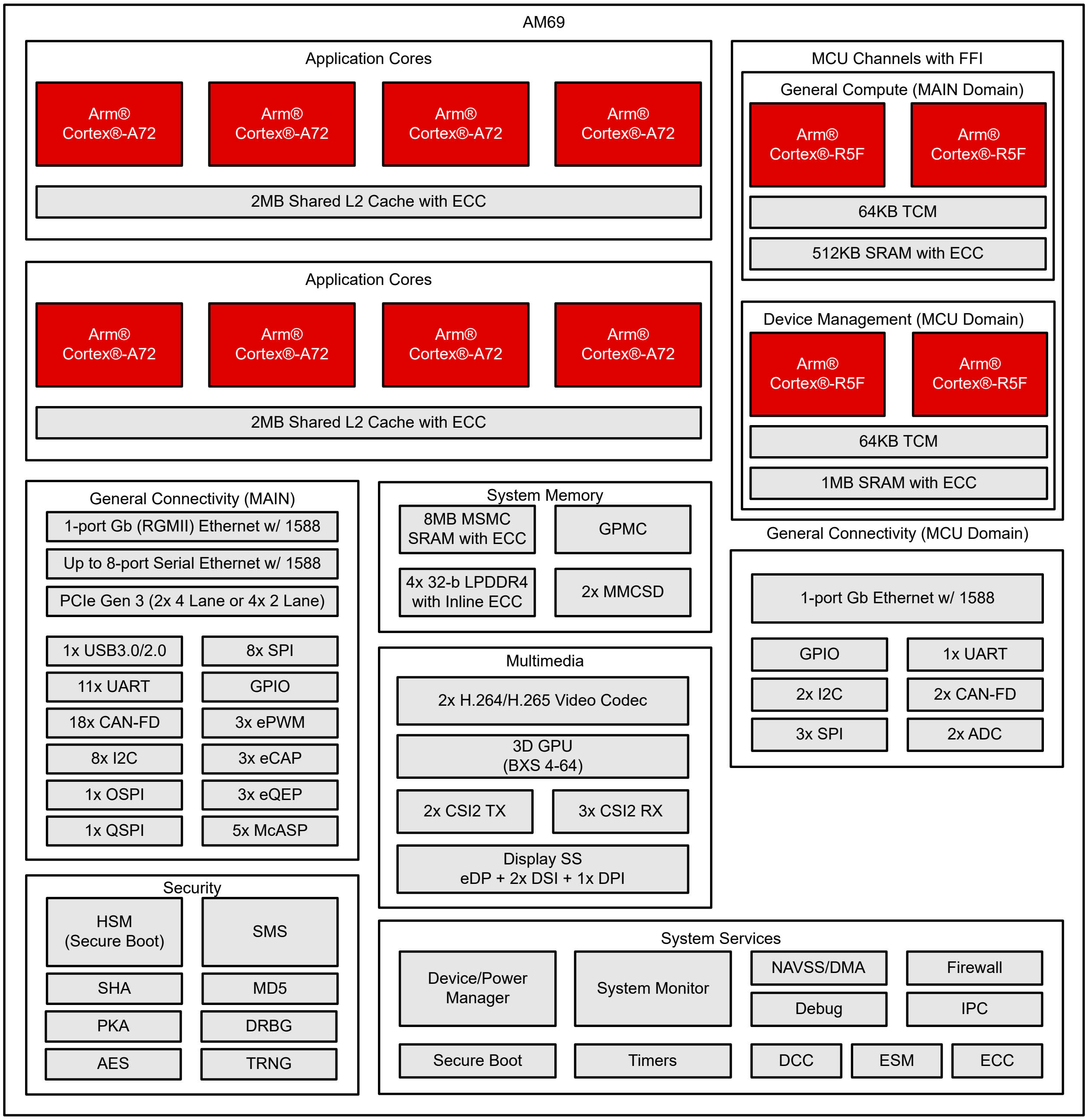

Figure 3-1. AM69 Block Diagram with Subsystems

4 Use Cases on AM68 and AM69

In today's fast-evolving technological landscape, the demand for general-purpose computing and peripherals is on the rise across a wide spectrum of applications, including both established domains and emerging products. This section introduces a range of popular use cases, each characterized by unique input requirements, such as computational intensity, high-speed interface demands, and display specifications. We will explore how our family of processors, the AM6x series, caters to this diversity of application needs.

To illustrate these capabilities, real-world examples from various industries will be presented in this section. These examples span across applications like Human Machine Interfaces (HMI) in manufacturing settings, Programmable Logic Controllers (PLC) for industrial automation, and Industrial PCs (IPC) used in diverse sectors. These case studies will provide concrete insights into how our family of processors actively contributes towards improving and advancing technology in practical situations.

4.1 HMI

A Human Machine Interface (HMI) serves as the vital bridge between a machine and its user, providing a graphical representation of the machine's status while enabling the user to control the device by sending commands through a processor. HMIs find applications in a wide array of industries, including industrial manufacturing, factory automation, building automation, and energy storage, among others, where a visual display is required to interact with machines.

HMI typically incorporates a processor to run the Operating System (OS) and execute custom applications, a high-resolution display(s) or touch screen for input, a GPU to bring the graphics acceleration to life for the user, and high-speed interfaces such as USB, PCIe, and ethernet for connectivity to outside world. There are many different levels to HMI ranging from low end to high end that utilizes multi core processors to achieve high levels of compute. Nevertheless, the implementation remains consistent as seen in Figure 4-1 showing a block diagram of a typical HMI.

The AM6x processors, such as the AM68 or AM69 devices, are ideally suited for HMI applications, spanning the mid to high end of the spectrum, effectively ushering customers into their next generation of requirements. Figure 4-1 portrays a typical block diagram for an HMI using AM68 or AM69 devices. The flexibility of this application allows for scalability based on the specific AM6x family device in use.

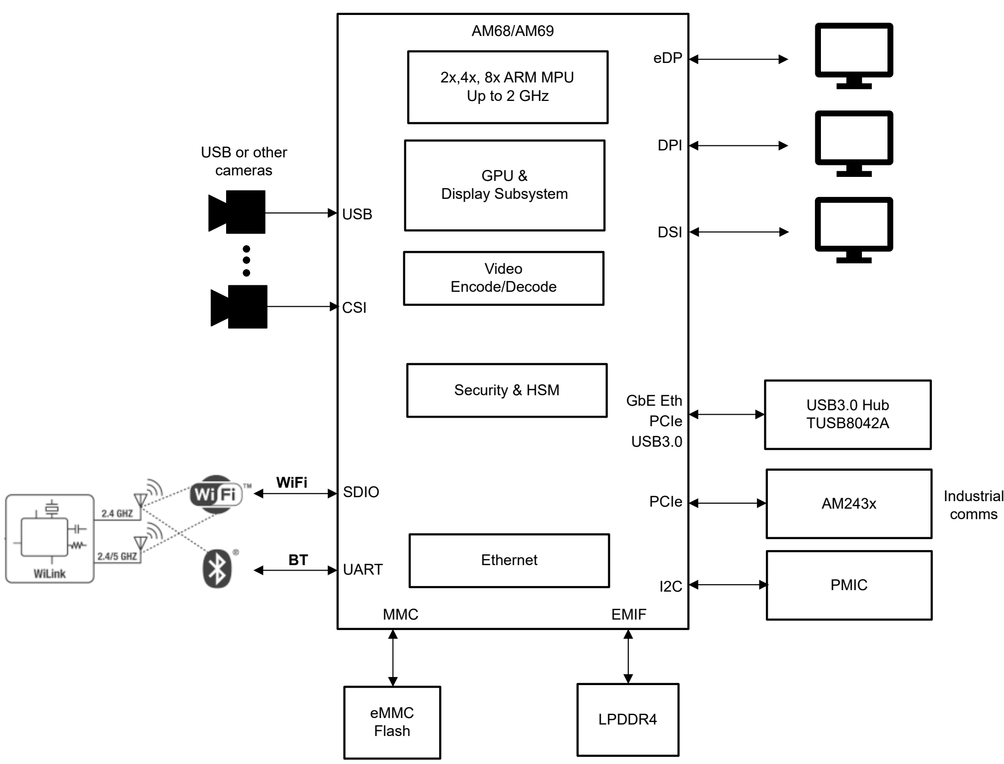

Figure 4-1. HMI Box Block Diagram on AM68/AM69

Figure 4-1 shows the typical block diagram for an HMI using AM68 or AM69 devices. This application can be scaled up or scaled down based on which device from the AM6x family is being used. The processor would interface through PCIe or ethernet with an external module such as a PLC or other controller so that it can acquire the proper data to display to a screen. The data displayed could be a pressure gauge, a motor encoder showing RPMs, or status of a machine. From there, the operator is able to decide what is needed next: Should they utilize USB3 to upload a new test program or data? Should they employ PCIe Gen 3 to write a set of data to an SSD drive? Or should they simply push a button to send a new command back to the machine, acknowledging the status?

Customers play a pivotal role in developing the software for interpreting and displaying this data on the screen, where the GPU comes into play for demanding processing tasks. With the Linux based SDK for our processors and their support in mainline kernel, the integration of custom applications onto our platform is streamlined. Moreover, the CSI2-RX interface facilitates the connection of multiple cameras to the HMI, making it ideal for applications requiring area monitoring and setting surveillance.

For projects with more advanced requirements, our Analytics variant of the AM6x processors empowers you to delve into advanced analytics for camera inputs, turning your regular HMI into a Smart HMI, refer to the whitepapers: Advanced AI Vision Processing Using AM69A for Smart Camera Applications and Advanced AI Vision Processing Using AM68A for Industrial Smart Camera Applications for how Edge AI can take your project to the next level of the industrial revolution.

4.2 Controllers and PLC – Programmable Logic Controller

Industrial 3.0 targets the automated processes using logic processors and information technology. Industrial 4.0 targets the increased automation for production processes within the manufacturing industry, including smart factories, smart manufacture, and so on. The AM6x family of processors targets both these revolutions and then into the next Industrial 5.0 utilizing analytics variants of the family.

Automation in an industrial setting is crucial to ensure that every machine is operating and performing the task it is supposed to do. AM6x devices are able to be utilized as a controller through the high compute A72 cores and the wide array of connectivity peripherals. PCIe Gen3, USB3.0, and multiple ethernet ports are a critical requirement for a controller as this will interpret how many modules and sensors can be connected centrally to make a decision based on the input data.

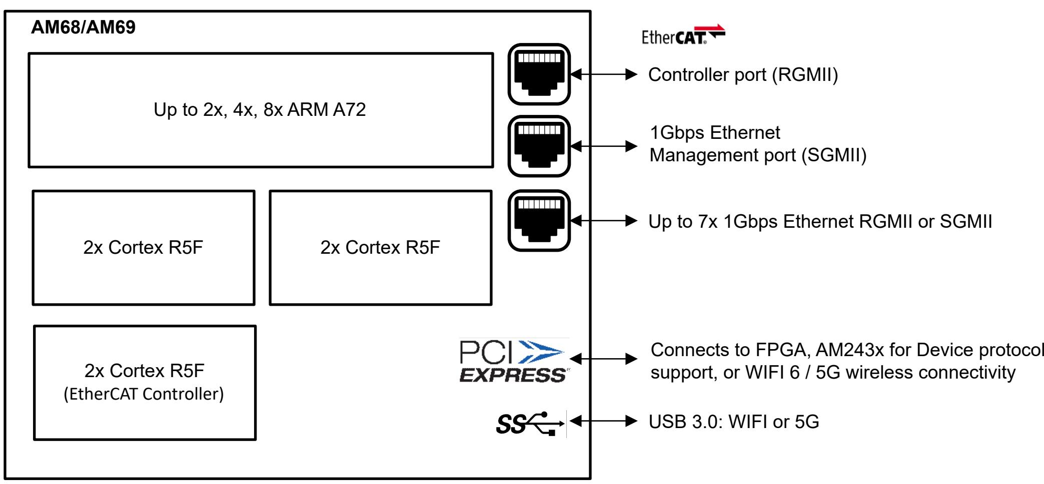

Figure 4-2. Programmable Logic Controller Block Diagram

Figure 4-2 illustrates the data flow for a PLC use case example on the AM68/AM69, which involves capturing data from an external sensor or module as an input, sending the data digitally to the powerful A72 cores in the SoC, make a pre-determined decision and then send an output command to the rest of the system which could be a pump, light or solenoid.

The broad family of AM6x processors are ideal for PLC's in their own unique ways. AM68 can be a simpler PLC that requires just a few high-speed interfaces and 2x ARM A72 cores for higher compute performance. The

AM69 is a maximum use case SoC that not only requires many high-speed interfaces with multiple PCIe ports or ethernet ports but also needs to use the 8x CPU cores in order to achieve maximum computability. Additionally, there are other devices in the TI processor family that can bridge the performance gap as a PLC such as DRA821U, DRA829J/V, AM62, AM64. Please refer to the respective product pages for more information.

4.3 Industrial PC (IPC), Single Board Computers (SBC), and Modules

An Industrial PC, often referred to as an IPC, is a rugged and specialized computer designed for use in industrial environments. They are used for applications like process control, data acquisition, and real time monitoring in industries like building and factory automation. Industrial PCs encompass a broad spectrum of end equipment solutions, addressing the diverse needs of today's industrial landscape.

Single board computers (SBC) are compact computer systems built on a single circuit board OR can be produced in a module form that connects to a bigger common product carrier board. SBCs and Modules usually include a processor, memory, high speed interfaces, and other essential IO interfaces. On a module, the IO connections are usually pinned out to a standard edge connector so that it can interface with a common carrier board. These applications represent some of the most versatile end equipments that can be realized with our TI processors.

In a factory automation environment, the block diagram of an Industrial PC and similarly an SBC is as described in Figure 4-3. These products follow a structured path critical to seamless and efficient operations. Initially, data is acquired from an array of sensors, devices, and machinery within the factory, capturing vital information related to processes, environmental conditions, and more. This raw data is then channeled into the industrial PC through a variety of communication interfaces, ranging from analog-to-digital converters to digital inputs and ethernet connections.

At the heart of these products lies the processor, a central component responsible for efficiently and accurately processing incoming data. This entails real-time analysis, the execution of control algorithms, and decision-making logic. The processor's capabilities play a pivotal role in optimizing the efficiency and productivity of factory operations. Based on the analysis, the control signals are transmitted to end devices, including actuators, motors, and additional sensors, orchestrating precise and coordinated actions across the factory floor.

Moreover, Industrial PCs facilitate seamless communication with other factory systems, including Programmable Logic Controllers (PLCs) and Human Machine Interfaces (HMIs), enabling comprehensive connectivity and transfer of information. Texas Instruments processors offer a comprehensive solution at every step of this intricate industrial computing journey, ensuring robust, efficient, and interconnected operations in the manufacturing sector.

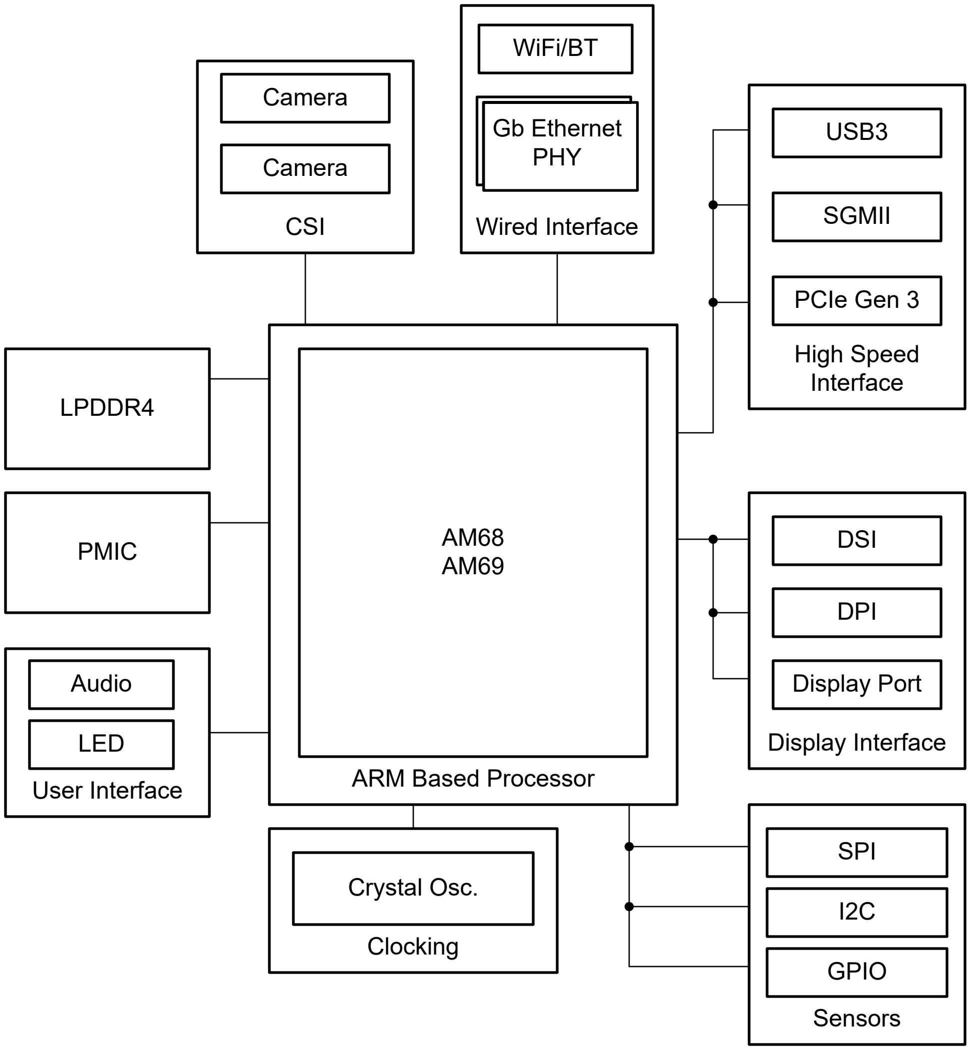

Figure 4-3. Single Board Computer Block Diagram

5 Software Tools and Support

Our large portfolio of Arm®-based application processors offer a broad range of efficient edge-computing performance for automotive, industrial, and IoT devices. We use a system-on-chip (SoC) architecture that delivers performance without sacrificing critical system resources, such as power, size, weight, and cost. Our development platforms, which have hardware, open-source software, and tools, help customers to get their products to market fast. While being such powerful processors, the application programing on AM68 and AM69 is made simpler and faster with adoption of Yocto Linux and mainline Kernel along with quarterly SDK releases and CI/CD.

5.1 Linux Software Development Kit (SDK)

The Processor Linux SDKs are unified software platforms for embedded processors providing easy setup and out-of-box access to benchmarks and demonstrations. Components provided in the SDK are u-boot, kernel, filesystem, Linux drivers, and more. Firmware builder package is used for the remote core and hardware accelerator drivers.

The SDK provides features such as:

- Long-term stable (LTS) kernel support on Arm® Cortex®-A72
- Board-support package (BSP)
- Yocto Project®-based file system
- Out of box Industrial Qt® software-based HMI demo mimicking "operator level" of Industrial automation demonstrating integrated display, graphics acceleration, CSI and Ethernet / Wi-Fi connectivity.

5.2 SDK Demonstrations and Benchmarks

The SDK provides the building blocks for customers to start their development on any of the use cases discussed in this paper for AM68 and AM69. There is a rich set of benchmarks and SDK demonstrations which can be leveraged by the customers. These benchmarks can be accessed with the SDK performance guides below.

AM68 SDK performance guide	Link
AM69 SDK performance guide	Link

The SDK comes with a few out of box demonstrations, such as those described in the following sections.

5.2.1 TI Apps Launcher

TI Apps Launcher is a QT-based application launcher for TI Platforms. Currently, TI Apps Launcher incorporates following applications across all supported platforms.

- Industrial HMI
- Live Camera
- Benchmarks (System and GPU)
- Firefox
- SoC Stats

For details on this, please refer the SDK documentation for AM68 and AM69.

5.2.2 Seva Store

Seva Store is TI developed Demo Gallery Tool which allows users to download and install demos on the target as docker containers. Developers can host their demos as docker images on any public docker registry and link them to Seva Design Gallery. The Seva Design Gallery interacts with the Seva Control Center to easily launch demos from a predetermined source using docker-compose. The Seva Control Center is built using Flutter and Go. To know more on how Seva Control Center works, refer to this link.

5.2.3 Wi-Fi Demo

The AM68 and AM69 SK board have a PCIe M2E Key interface port which is connected to an Intel-9260 Wi-Fi card. Using this, a Wi-Fi demo can be set up such that the board can act as both a Wi-Fi Access Point (AP) or a Wi-Fi Station that can connect to an external access point like a router or hotspot when powered up. The board also starts iperf3 automatically on the access point interface, and the user can run iperf3 on their devices to test the throughput. Refer to the SDK documentation for AM68 and AM69 for details on this.

5.3 Training Academy

The training academy for AM68 and AM69 cover the basics of getting started and provide a gateway for new customers into the TI's ecosystem. These academies also include a comprehensive Linux Academy spanning over topics such as:

- Linux System Design: Gives an overview of the entire design process. It includes a checklist to capture many different aspects of the design process.
- Evaluating Linux: This shows several ways to explore Linux right out-of-box on a TI's development board. This module allows users to start interacting directly with the SDK via a wide variety of labs to teach common practices, as well as tips and tricks to speed development.
- Develop Linux on TI EVM: Discusses how to modify the SDK during the development process. It covers boot modes, flashing, rebuilding core components like U-Boot, Linux kernel, and more. The Linux SDK and a TI's development board allows user space application development to begin, even before custom hardware has been produced.
- Porting Linux to Custom Hardware: The goal of most embedded systems is to get Linux up and running on custom hardware. This process is covered in the Porting Linux to Custom Hardware section. Other Linux customizations are also discussed in this section.
- FAQs: Covers the most frequently asked questions on the TI's E2E forum.

AM68 Academy	Link
AM69 Academy	Link

6 Conclusion

The AM68 and AM69 are proving to be leading devices for general purpose applications with multiple displays, graphics acceleration, and high-speed interfaces. The heterogeneous architecture with multiple cores and accelerators provides flexible ways to optimize performance for the end application. The possibilities do not stop there as technology continues to progress and we find new areas that these processors can fit.

Developers can start by exploring the free training academies to get started with the device. The AM68 or AM69 is ready for the developer to start developing applications with the starter kit boards and the Processor SDK Linux. Documentation, prebuilt images, and demonstrations are available from the product page for these devices.

7 Relevant Links

AM68 product page	https://www.ti.com/product/AM68
AM68 SDK	https://www.ti.com/tool/download/PROCESSOR-SDK-LINUX-AM68
AM68 academy	Link
AM68 Starter Kit	https://www.ti.com/tool/SK-AM68
AM69 product page	https://www.ti.com/product/AM69
AM69 SDK	https://www.ti.com/tool/download/PROCESSOR-SDK-LINUX-AM69
AM69 academy	Link
AM69 Starter Kit	https://www.ti.com/tool/SK-AM69

8 References

1. Industrial/Medical Semiconductor Forecast, 2018 Edition, Market Analysis and Forecasts to 2023, Semicast Research Ltd.
2. Texas Instruments, Edge AI smart cameras using energy efficient AM62A processors Technical White Paper