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AN AVNET COMMUNITY

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Industrial Control and Automation

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Industrial Control and Automation

element14 is a community of over 800,000 makers, professional engineers, electronics enthusiasts, and everyone in between. Since our beginnings in 2009, we have provided a place to discuss electronics, get help with your designs and projects, show off your skills by building a new prototype, and much more. We also offer online learning courses such as our Essentials series, video tutorials from element14 presents, and electronics competitions with our Design Challenges.

Industrial control and automation continue to evolve, as Industry 4.0 and Industrial IoT transform manufacturing production, logistics, and operations management, while taking advantage of edge-cloud technology. This eBook covers features and trends in industrial control and automation today, with a special emphasis on NXP Semiconductor's i.MX RT 1170 and i.MX 8M Plus processors.

element14 Community Team

Introduction

Industrial control and automation continue to evolve as Industry 4.0 and Industrial IoT (IIoT) transform manufacturing production, logistics, and operations management. Manufacturing lines have become complex systems of devices that achieve synchronization due to real-time processing and deterministic communication. Once a product is fully manufactured, factory logistics distributes the product using intelligent devices able to autonomously organize warehouse storage or shipping to market. The operational management of globally distributed factories requires systems enabled with secure connections to monitor logistics and manufacturing operations. The cloud enables solutions for factories, so information from all automation layers can be securely transferred from the Edge to the Cloud in order to optimize the integration of IT (Information Technology) and OT (Operational Technology) systems. This eBook discusses trends of industrial control and automation with an emphasis on NXP Semiconductor's i.MX RT 1170 and i.MX 8M Plus processors.

CHAPTER - 1

INDUSTRIAL CONTROL

Industrial control is a key element in any factory automation process. It may vary from a simple panel-mounted controller to large interconnected and interactive distributed control systems. It can also be the head of an automated cell managing slice I/O clusters or drives. It is supported by industrial processes and control systems like SCADA solutions (Supervisory Control and Data Acquisition) at server level and PLCs (Programmable Logic Controllers), RTUs (Remote Terminal Units), DCSs (Distributed Control Systems), and IEDs (Intelligent Electronic Devices) at Edge Level.

PLCs are crucial to industrial control; their primary function involves real-time supervision of individual stations or machines, such as AC drives, servo drives or sensors, as well as stations where low deterministic latency is desirable. They connect to OT (operational technology) networks, IT networks and, eventually, to the cloud. To make the interaction of operators with a PLC smarter and more secure, near-field communication (NFC) can replace DIP switches, service UARTs, and other electromechanical elements. Higher performance processing enables faster assembly lines, the reduction of control loop timing, and increased production output.

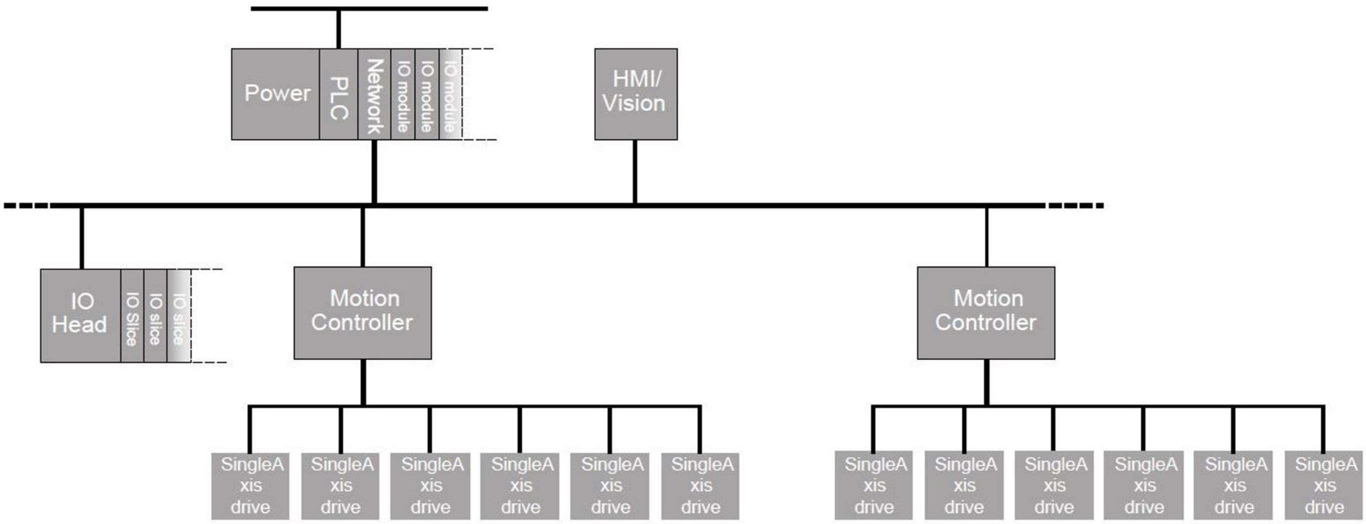


Figure 1: A typical automation cell

CHAPTER - 2 NEXT GENERATION INDUSTRIAL AUTOMATION

Industrial Internet of Things (IIoT) aims overall to build distributed autonomous systems in order to bring more agility to manufacturing systems, while adjusting to environmental condition changes in real time. However, these systems face the following challenges:

Flexibility: Designing flexible factories organized in distributed, modular units

Connectivity: Connecting a production line from edge to cloud, while properly managing real-time critical data and ensuring proper bandwidth for heavy traffic users (e.g. vision systems)

Functional Safety: Improved availability, efficiency, and speed

Security: As the factory floor becomes more fully connected and geographically distributed, it also becomes much more vulnerable to physical attacks. It also becomes more vulnerable to remote attacks, as it encompasses many devices connected to the cloud, so more opportunities exist for a hacker to penetrate the system.

New Developments

Advances in Artificial Intelligence, Edge Computing, and connected networks have enabled several new processes that enhance factory automation, predictive maintenance, functional safety, and overall efficiency. This section will take a closer look at these new developments:

Machine Learning (ML): Machine learning (a subset of AI) harnesses statistical techniques to grant computers the expertise to learn without being explicitly programmed. Figure 2 illustrates the critical elements, as the machine is trained to identify the data needed to perform its assigned job. The ML system uses computational learning theories like Bayesian probabilities, probabilistic techniques, and kernel methods, as well as pattern recognition techniques and neural networks.

Edge Devices: Cloud computing users depend on computational resources located outside of their local network boundaries. Edge Computing, however, returns a substantial bulk of the processing to the confines of the local network. With a reduced amount of data uploaded and lower network latency achieved by avoiding a round trip to the cloud, real-time decisions become a possibility. In cloud computing, common jobs include filtering, pre-processing, storing, and buffering data. Integrated Neural Processing Units (NPUs), adaptive computing, and other advancements bring edge devices to the next level, pushing the boundaries of AI/Machine Learning, application acceleration, and more.

Converged Industry Networks: Network convergence brings together voice, data processing, and video, and combines them in a single network. Connected networks and platforms can be combined, enabling different networks in different locations to communicate with each other using specific protocols and common standards.

Time-Sensitive Networks (TSNs): These systems make deterministic Ethernet possible. TSNs provide evolution for industrial real-time networks, and are a set of IEEE® 802 Ethernet sub-standards defined by the IEEE TSN task group. TSNs assist the convergence of OT and IT networks, as required for Industry 4.0 compatible OEM design solutions.

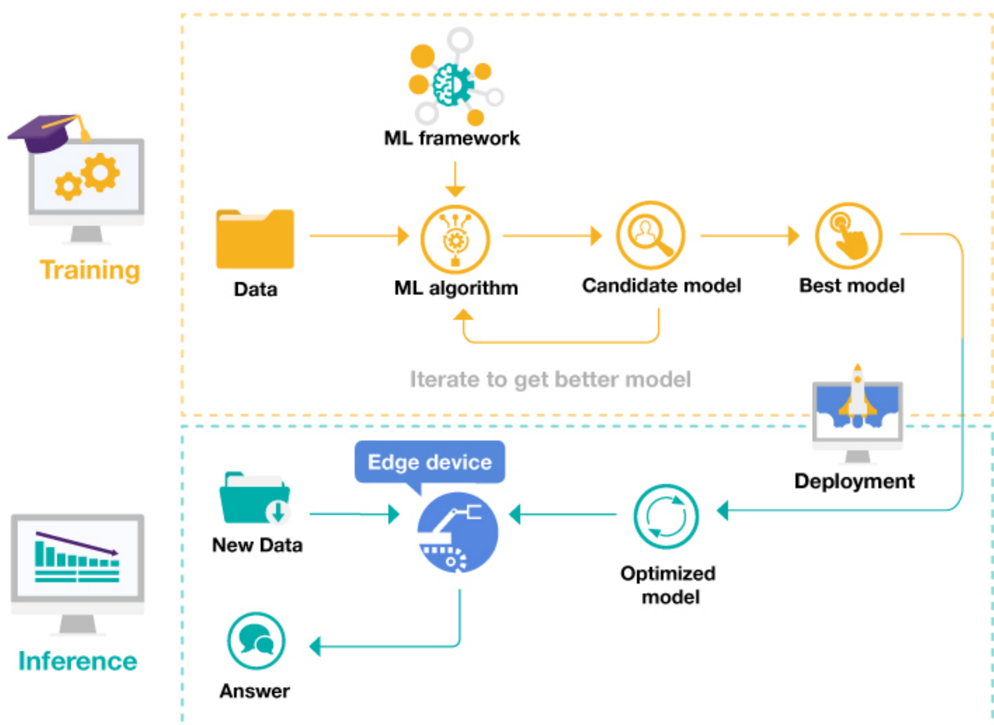


Figure 2: ML workflow

Motor Drives

Motor drives are frequently used in factory automation. There are three main types of motor drives: DC, AC, and servo. DC drives can be used with brushed and brushless DC motors, and stepper motors. AC drives, or variable frequency drives (VFDs) are used mainly with Asynchronous Induction motors; they are popular due to their simplicity, reliability, efficiency, and direct operation from an AC line voltage. Servo drives are typically used with permanent synchronous motors; they provide high performance, high-precision, and high efficiency systems. High-performance motor control is characterized by smooth rotation over the entire speed range of the motor, full torque control at zero speed, and fast acceleration and deceleration.

Industrial motor control requires high-efficiency power management ICs, RTCs, thermal-efficient power drivers with current monitoring capability, USB and CAN transceivers, and voltage level translators. A motor supported by a microcontroller enables rapid simplification of the design process. This may involve high-resolution timers, complete software enablement, and even high voltage analog components like integrated voltage regulators, CAN-FD physical layer interfaces, amplifiers, and FET gate drives. Simple control algorithms work on the most economical silicon, whereas more advanced and efficient ADRC and field-oriented control (FOC) loops need additional analog feedback and processing power.

Fail-Safe Motor Control

Fail-safe technology is critical in the industrial world, and essential in applications such as cranes, assembly line robots, and lifts. Implementing fail-safe technology ensures that all Safety Integrity Level (SIL) standards are met as described in the IEC 61508 standard, and helps keep people, products, and property safe.

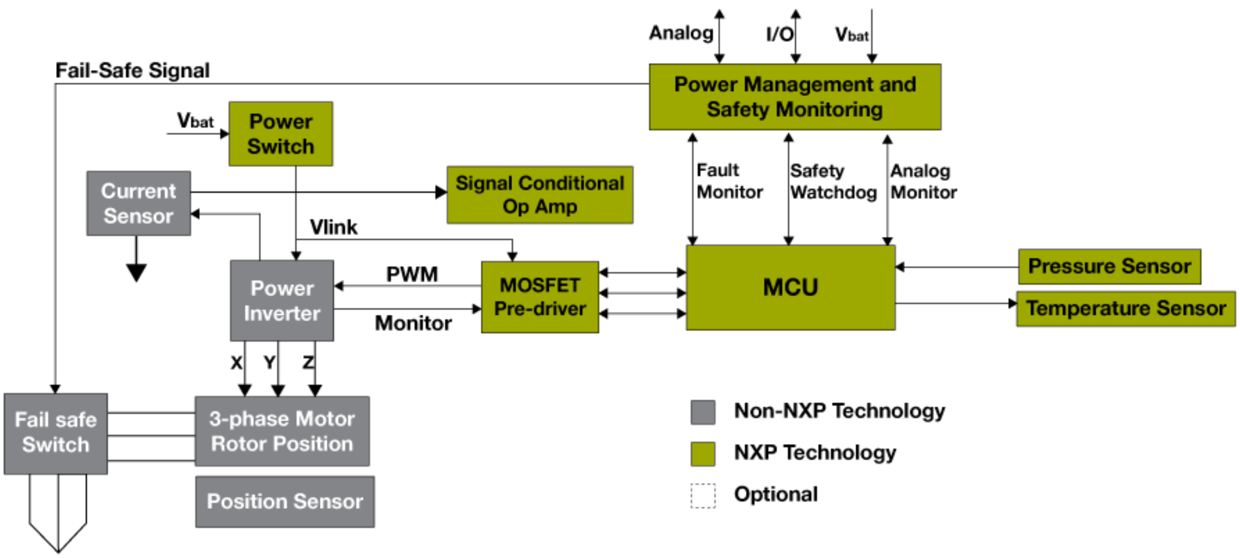


Figure 3: Fail-safe motor control

Robotics

Robot motion control technologies offer low latency, computing performance, real-time open-source operating systems, and embedded connectivity to solve multi-axis motion requirements. Robotic systems require a variety of different communications interfaces. Some are purpose-built MCUs and silicon for proprietary shielded radio systems, as well as MBUS, BLE, ZigBee, sub-GHz radios, SigFox, 802.15.4 Thread mesh networking, and wireless. For mobile robotics, NXP's RoadLINK™ V2X modems are good

solutions for vehicular communication, and can pave the way for the next generation of autonomous vehicles. Motion control solutions for robotics require computing performance and low latency, as well as embedded connectivity to meet the needs of multi-axis motion control. A multi-axis motion controller coordinates the motion of an automated system on multiple axes. Stepper motor motion control is also a critical component, as the output electrical pulse signal establishes precise velocity and servo control position.

Cloud-Based Condition Monitoring

Condition monitoring is the process of collecting and analyzing equipment parameters and key operation indicators. The goal is to predict whether an asset will malfunction, how it will malfunction, and how much time is needed to repair or replace it. As such, the use of condition monitoring allows maintenance to be scheduled, or other actions to be taken to prevent damage and avoid production downtime.

What makes operation management challenging is that machines, systems, devices, and objects are oftentimes geographically distributed. This results in critical challenges for maintenance teams. In this context, cloud-based condition monitoring allows technicians and managers to access data from any equipment at any time, using a computer or their smart devices. In addition, cloud-based condition monitoring solutions have several advantages compared to on-premise solutions, including access from anywhere, advanced analytics, configurable dashboards, and scalability.

The rapid development of Industry 4.0 revolves significantly around the Internet of Things. Large numbers of these IoT “things” are efficiently interconnected, especially in industrial automation, which leads to condition and controlled monitoring to increase productivity. In this respect, many of the public cloud service providers offer IoT services using standard protocols for real-time storage and data aggregation. This makes it possible to access real-time data online, reduce operational risks, and lower service costs.

Factory automation in the Industry 4.0 era promises better productivity, as it connects numerous components with granular control and condition monitoring. Anomalies in sensor readings can be successfully flagged, giving early signals regarding potential system or equipment failure.

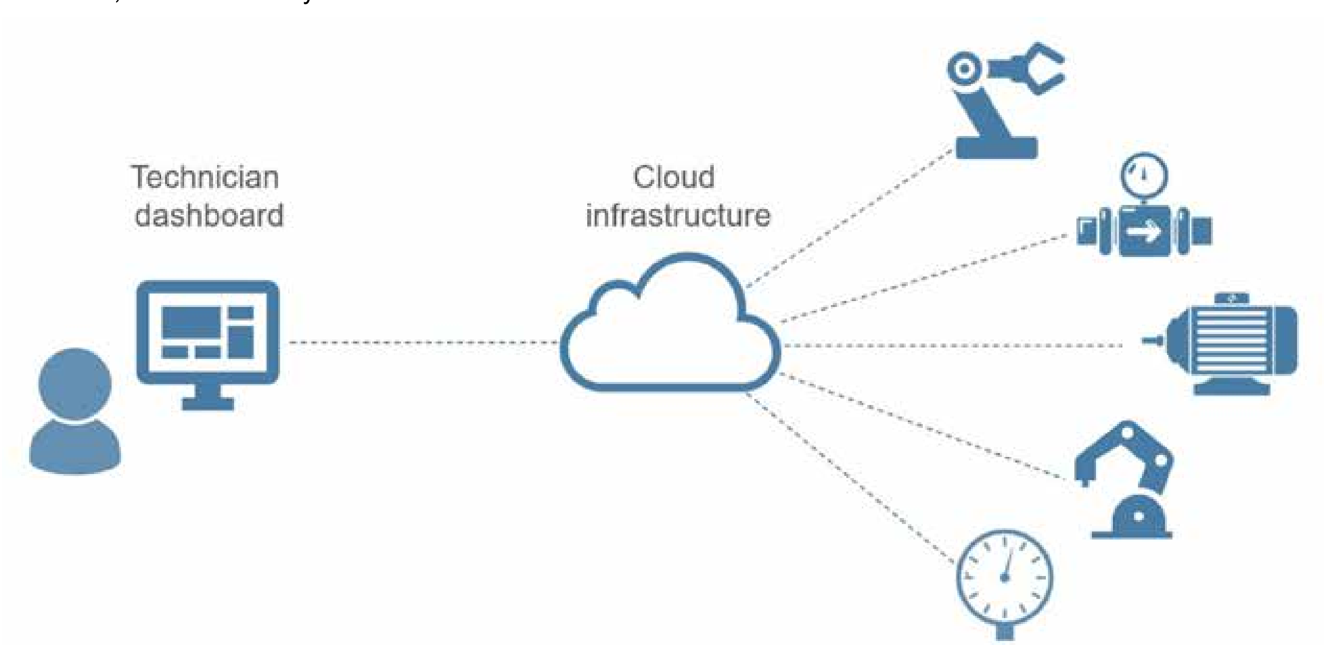


Figure 4: Cloud-based condition monitoring

Anomaly Detection

In any automation system, problems, errors, and machine failures must be detected and handled before serious issues occur. Anomaly detection can prevent serious issues by keeping a constant eye (via sensors) on machine health and flagging unexpected data. A deep learning approach effectively identifies anomalies in data, and shows better performance on more complex and noisy data than standard machine-learning techniques.

As shown in Figure 5, a small and lightweight sensing tag based on the NTAG SmartSensor, combined with an MCU with Machine Learning capabilities, provides a way to add sensory and logging capabilities to existing machinery without interfering during normal operations. The early detection of anomalies allows preventive maintenance and avoids production losses.

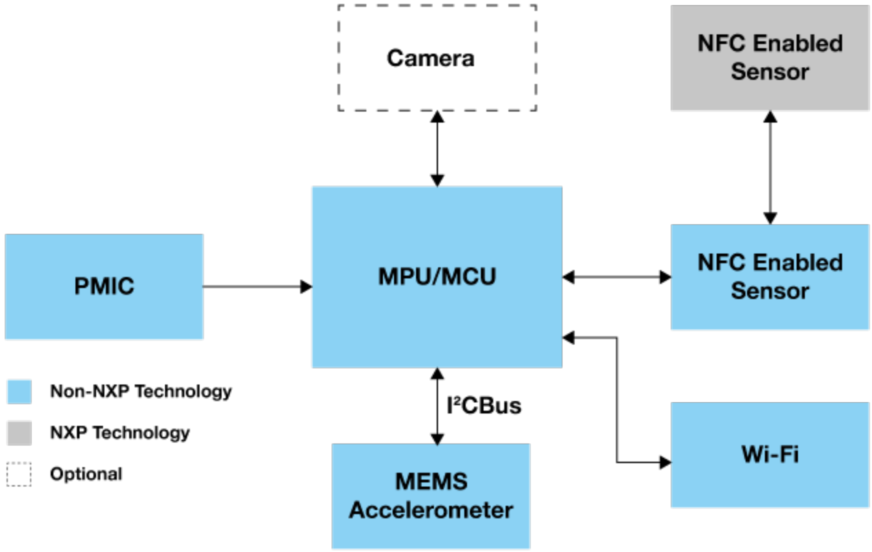


Figure 5: Block diagram of anomaly detection

CHAPTER - 3 INDUSTRY 4.0

Industry 4.0 is an industry-wide initiative whose mission is to create the intelligent industrial enterprise of the future. By merging information technology (IT) and operational technology (OT), manufacturing organizations are building next-generation smart systems to optimize manufacturability, improve operations, enhance customer support, and analyze real-time data provided by the Industrial Internet of Things (IoT). In its most reduced form, the IoT concept connects embedded systems to the larger world. The challenge is to implement the requisite technologies to realize Industrial IoT.

Time-Sensitive Networks (TSNs)

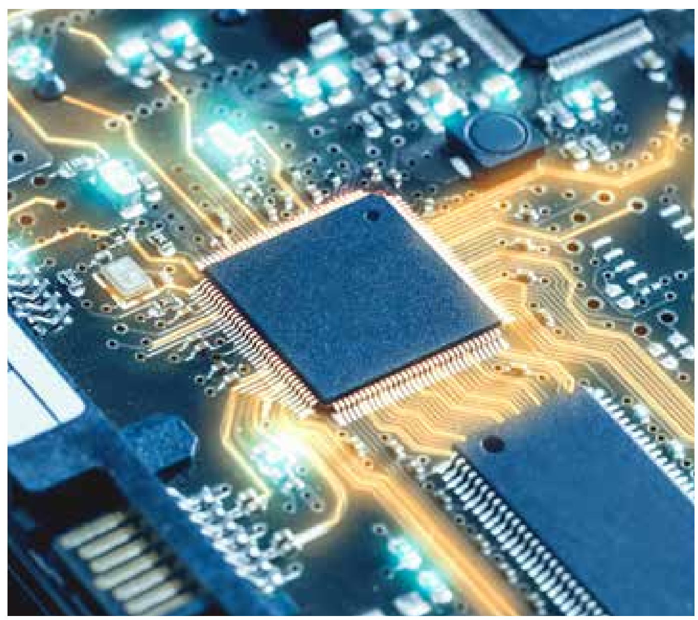
Time-Sensitive Networks (TSNs) refers to a compendium of standards developed and steered by the IEEE 802.1 TSN-Task Group. They are essential to realizing the IIoT and Industry 4.0. The typical hardware implementation (Layer2 in the OSI model) leads to simpler system management and allows unified control of high-bandwidth and time-critical data application implementation. A TSN encourages OT (Operations Technology) and IT (Information Technology) convergence, mobilizing Gigabit Ethernet to facilitate high bandwidth, even with legacy IT equipment. It also adds frame replication and elimination, time-aware shaping, frame pre-emptions, and other attributes to satisfy all OT network demands.

Functional Safety

Functional safety standards applicable to industrial control systems are industry dictated and derived from IEC 61508. They include hazard and risk analysis, risk mitigation measures, and system safety. Integrated safety features such as self-testing and hardware-based redundancy monitors eliminate random hardware failures. The IEC 61508 document defines four general SILs, with SIL 4 denoting the most stringent safety level.

Processing Power

Just as networks must support time-critical functions, so must processing. A real-time operating system (RTOS) helps ensure that a CPU is available to receive and process control packets when they arrive on a TSN-enabled port. The ability to respond to control packets also helps the CPU to address events coming to the processor from other inputs, and to execute loops controlling the system the processor is part of. These loops may need to run up to every 30 microseconds or faster—a degree of precision that a conventional IT-derived operating system cannot meet. The need for more automation requires increased processing capabilities in embedded controllers. Higher performance processing can be used to reduce control loop timing, moving robotic arms and assembly lines faster and increasing factory output. It can also increase the number of axes managed by a single motion controller, leading to robots with more articulated joints, which can operate in tighter spaces or perform tasks that the previous generation of factory robots could not address. Robots that can learn tasks from a human operator will require image processing, along with new Machine Learning algorithms.



Human-Machine Interfaces

Another function demanding processing power is the human-machine interface (HMI). Smartphone-inspired interfaces will increasingly permeate the staid world of industrial equipment. Easy-to-use, visual interfaces with multi-touch flat panels can be embedded in any industrial equipment, simplifying operator control of machines. High-resolution screens will enable viewing the output of high-definition (or better) cameras inspecting goods as they are manufactured. Driving these screens will be the same type of graphics processing units (GPUs) found in smartphones. HMIs are the perfect example of how the convergence of IT and OT systems is needed in the modern digital factory.

Security

The convergence of OT and IT increases the risk of security threats. In the past, operations were isolated—almost impenetrable from the outside world. A hacker would need a physical link to attack a machine. A converged industrial setting erodes barriers isolating operations, so that information can be shared among systems to improve efficiency. New barriers must be erected to ensure the integrity of systems while maintaining the permeability to data flow. The first step for equipment manufacturers is to secure processing platforms in their equipment. They must ensure that their systems execute only approved software and connect securely to other systems. These systems must be securely commissioned, periodically updated, and made to resist tampering with their hardware and software.

CHAPTER - 4 CORE TECHNOLOGIES

NXP's crossover processors and MCUs merge the simplicity of MCUs with the complexity of application processors into a hybrid device. These solve the growing demand for enhanced user experiences in intelligent and secure high-performance products. The i.MX RT1170 crossover and i.MX 8M Plus platform have capabilities well suited to industrial control and factory automation, including features that support AI, ML, edge computing, Industrial IoT, and vision-based applications.

The i.MX RT1170 Crossover Platform

Crossover processors deliver the performance, functionality, and capabilities of an applications processor-based design, but with the ease-of-use, low-power, and real-time operation with low interrupt latency of an MCU-based design.

The i.MX RT1170 is designed with the high-performing Arm® Cortex-M7 at 1 GHz and the Cortex-M4 at 400 Hz, as shown in Figure 6. It provides scalable HMI solutions with support for parallel and MIPI display controllers and cameras. For graphics acceleration, it takes advantage of the 2D pixel pipeline accelerator and 2D GPU with vector graphics acceleration, as well as embedded graphics software as part of the MCUXpresso SDK.

The i.MX RT series architecture allows users to connect with a variety of external memory types, including serial/parallel NOR, NAND, and RAM, as well as eMMC with Error Code Correction (ECC). The devices support a wide range of memory densities, power, and performance.

Also, the architecture features extensive connectivity options, like TSN-enabled MAC and CAN FD.

The Cortex-M4 core can be dedicated to time-critical control applications, such as sensor hub and motor control, while the central core runs more complex applications. The GHz Cortex-M7 core significantly enhances performance for ML, edge inference for voice, vision, and gesture recognition, natural language understanding, data analytics, and digital signal processing functions.

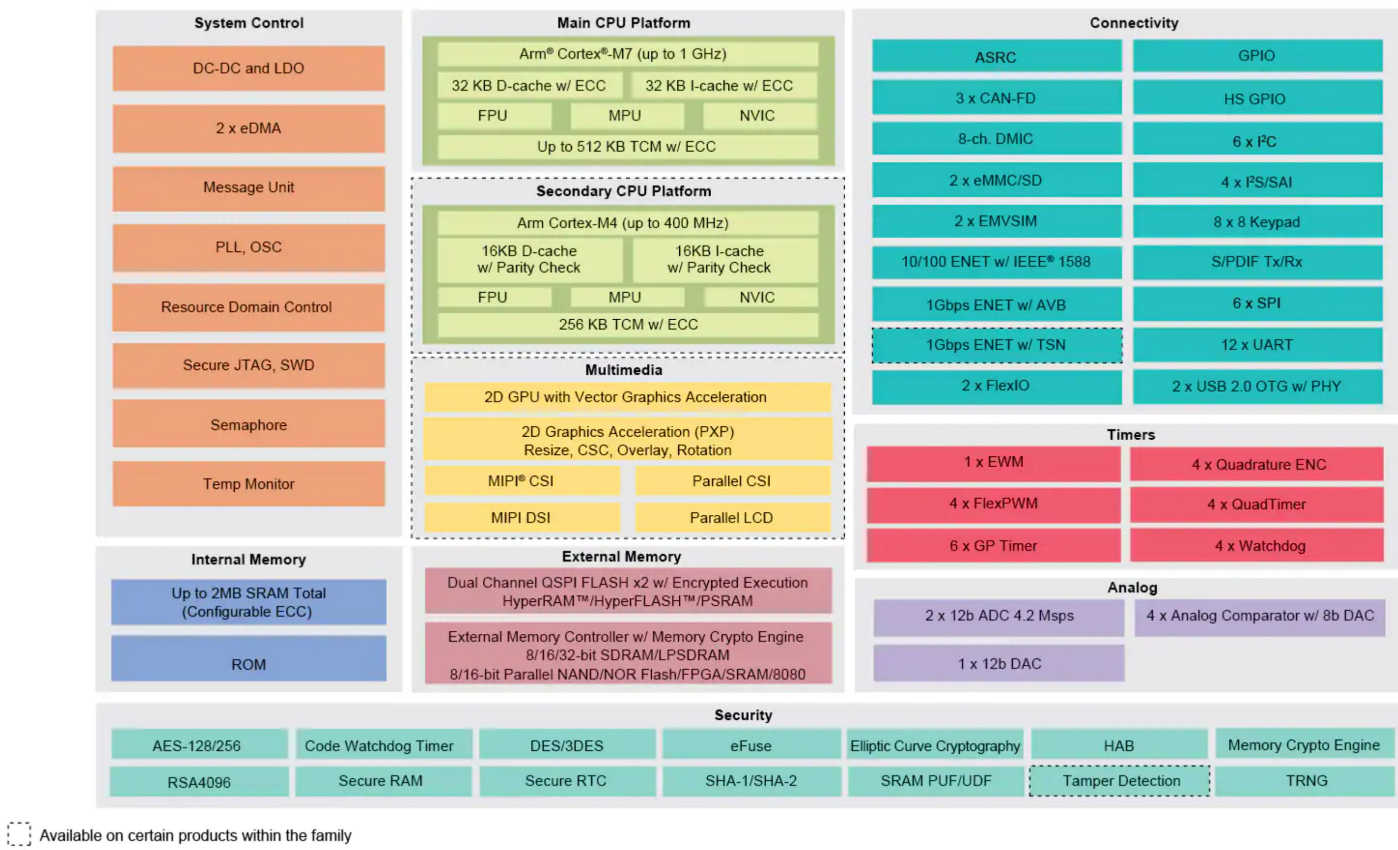


Figure 6: The i.MX RT1170 Crossover MCU block diagram

The i.MX 8M Plus with Arm® Cortex®-A53

The NXP i.MX 8M Plus applications processor enables Machine Learning and intelligent vision for the industrial edge and a wide range of other applications. Highlighted features include the integrated NPU, two integrated MIPI CSI camera interfaces, dual camera image signal processors (ISPs), and other multimedia capabilities.

As shown in Figure 7, the i.MX 8M Plus supports TSN Ethernet connectivity, which helps guarantee that data is transmitted at the right time for time-sensitive functions on the factory floor. In addition, two CAN-FD peripherals support low latency communications and networking functions. Combined with the other on-chip cores, peripherals, and interfaces, the i.MX 8M Plus enables a well-rounded industrial system and provides a range of edge-based ML capabilities for Industry 4.0.

The i.MX 8M Plus processor enables developers to bring their ML workloads to the edge, which is the closest point to the actual sensing, whether it be voice, vision, or anomaly detection. Developers can access the on-chip NPU, which has a 2.3 trillion operations per second (TOPS) performance to handle ML tasks approximately 30 times faster than the Arm core.the on-chip NPU, which has a 2.3 trillion operations per second (TOPS) performance, to handle ML tasks approximately 30 times faster than the Arm core.

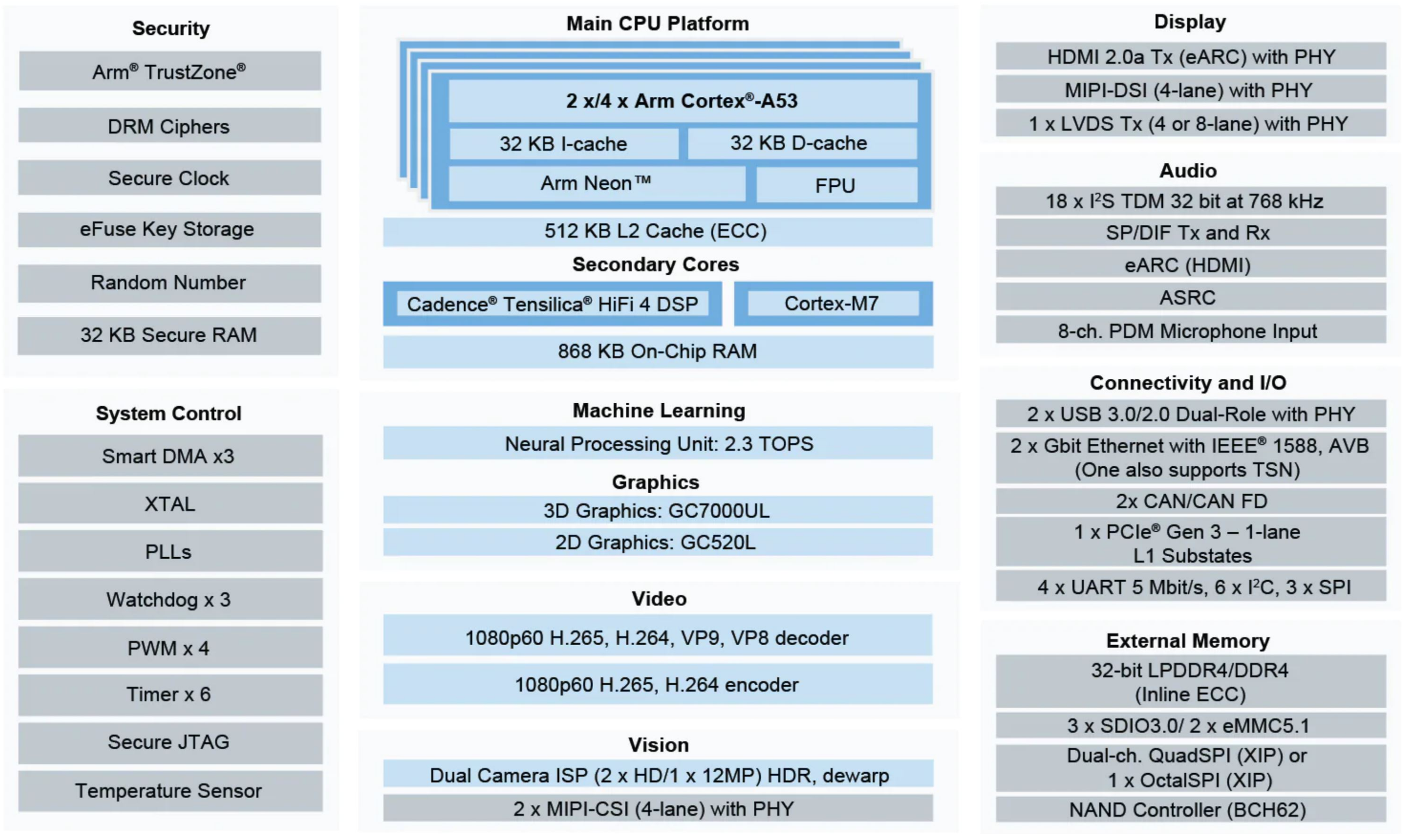


Figure 7: i.MX 8M Plus block diagram

CHAPTER - 5 RELATED COMPONENTS

This eBook covers current trends in industrial control, with an emphasis on NXP Semiconductor's i.MX RT 1170 and i.MX 8M Plus processors. To extend the information covered, the following supplementary guide discusses the types of components used for prototyping or product development.

8MPLUSLPD4-EVK Evaluation Kit for the i.MX 8M Plus Applications Processor

The i.MX 8M Plus EVK provides a platform for comprehensive evaluation of the i.MX 8M Plus Quad/Dual and i.MX 8M Plus QuadLite applications processors. It delivers high performance with power efficiency, Machine Learning, voice, and vision capabilities, advanced multimedia interfaces and Wi-Fi/BT for connectivity out-of-the box.

MIMX8ML8CVNKZAB Microprocessor, i.MX 8M Plus Quad, 1.8GHz, 32bit, -40 °C to 105 °C, FCBGA

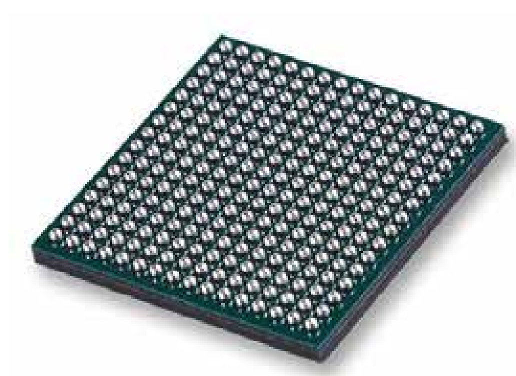
The i.MX 8M Plus applications processor is based on the quad-core Arm® Cortex®-A53 processor. It runs at up to 1.8 GHz with an integrated neural processing unit (NPU) that delivers up to 2.3 TOPS. As the first i.MX processor with a Machine Learning accelerator, the i.MX 8M Plus processor provides substantially better performance for ML inference at the edge. It is targeted for use in smart home, city, and Industrial Internet of Things (IIoT) applications.

MIMXRT1170-EVK Evaluation Kit, 32 Bit, i.MX RT Family, MIMXRT1176DVMAA, ARM Cortex-M4 / Cortex-M7

MIMXRT1170-EVK is an i.MX RT1170 evaluation kit (EVK) designed to evaluate i.MX RT1170 crossover MCUs. It includes key components and interfaces such as MIPI LCD and camera connectors, Ethernet, Micro USB, CAN and Arduino connectors, 6-axis e-compass, motor control interface, and SIM card slot.

MIMXRT1176CVM8A Microprocessor, 32 Bit, 800 MHz, i.MX RT1170 Family

i.MX RT1170 crossover MCUs are part of the EdgeVerse™ edge computing platform and are setting speed records at 1 GHz. This product family combines superior computing power and multimedia capabilities with ease of use and real-time functionality. The dual core i.MX RT1170 MCU runs on the Arm® Cortex®-M7 core at 1 GHz and Arm Cortex-M4 at 400 MHz, while providing high security. The i.MX RT1170 MCU offers support over a wide temperature range and is designed for consumer, industrial and automotive markets.



MIMX8ML8DVNLZAB Microprocessor, i.MX 8M Plus Quad, 1.8GHz, 32bit, 0 °C to 95 °C, FCBGA

The i.MX 8M Plus family focuses on Machine Learning and vision, advanced multimedia, and industrial automation with high reliability. It is built to meet the needs of smart home, building, city and Industry 4.0 applications. It features a powerful quad or dual Arm® Cortex®-A53 processor with a Neural Processing Unit (NPU) operating at up to 2.3 TOPS. It also has dual image signal processors (ISPs) and two camera inputs for an effective advanced vision system. The multimedia capabilities include video encode (including h.265) and decode, 3D/2D graphic acceleration, and multiple audio and voice functionalities. It offers real-time control with Cortex-M7. Robust control networks are supported by dual CAN FD and dual gigabit Ethernet with Time-Sensitive Networking (TSN).

8MMINILPD4-EVKB Evaluation Kit, ARM Cortex-A53/Cortex-M4

The i.MX 8M Mini EVKB provides a platform for comprehensive evaluation of the i.MX 8M Mini and i.MX 8M Mini Lite applications processors. It delivers high performance with power efficiency, multimedia interfaces, and Wi-Fi/Bluetooth for connectivity out-of-the box.

8MNANOD4-EVK Evaluation Kit, 32 bit, i.MX 8M Nano Quad, ARM, Cortex-A53, Cortex-M7

The i.MX 8M Nano EVK provides a platform for comprehensive evaluation of the i.MX 8M Nano and i.MX 8M Nano Lite applications processors. It offers performance and power efficiency with multimedia interfaces, NXP PMIC, and NXP Wi-Fi/BT solution for connectivity out-of-the box. Target applications include: building security, smart lighting, smart power, and more.

LS1028ARDB-PA REF Design Board, TSN For Industrial IoT (IIoT)

The Layerscape LS1028A applications processor for industrial and automotive includes a Time-Sensitive Networking (TSN) -enabled Ethernet switch and Ethernet controllers to support converged IT and OT networks.

SJA1110-EVM SJA1110-EVM Boards ROHS Compliant: Yes

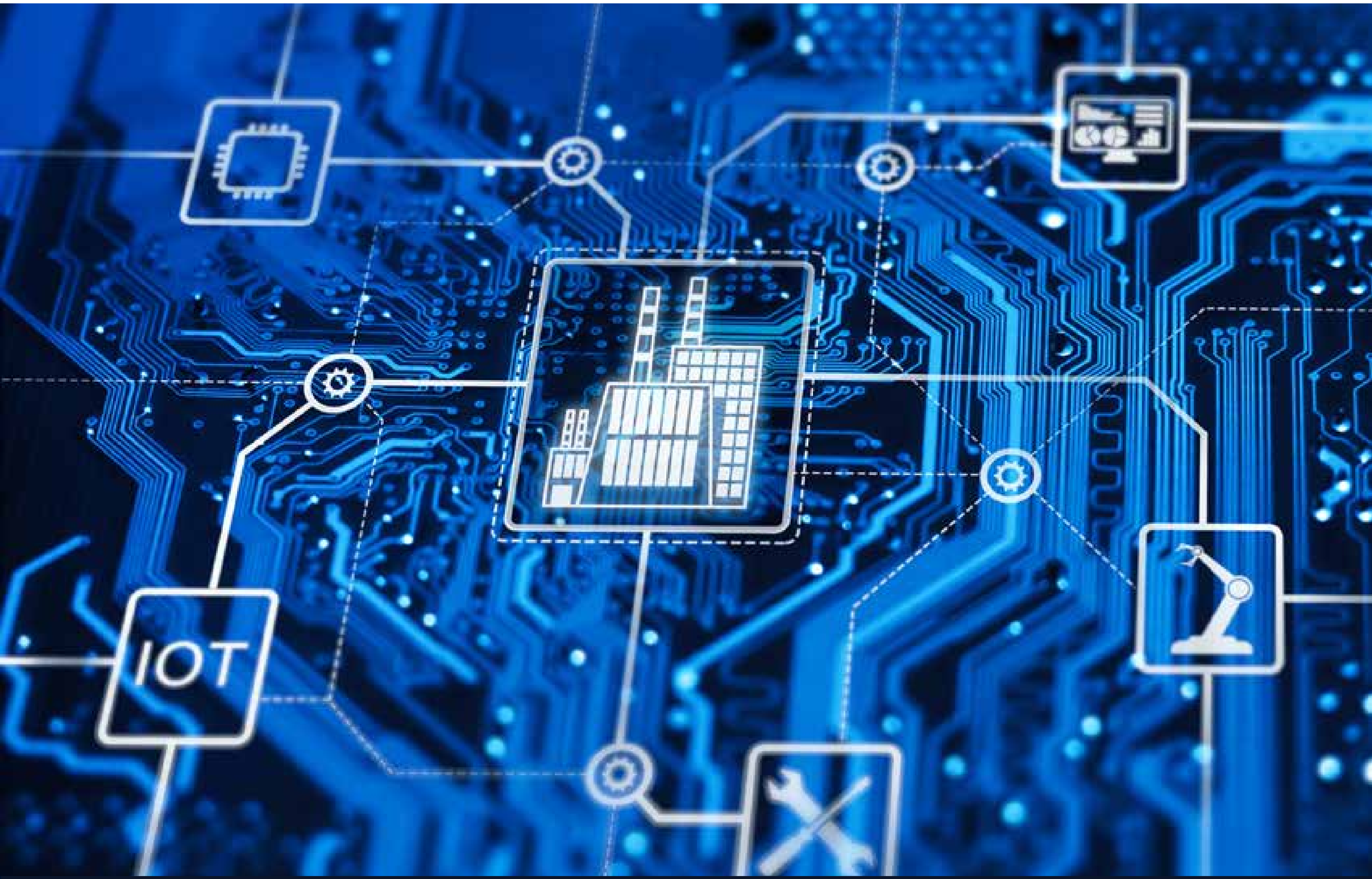
The NXP SJA1110 is a family of four pin-compatible and software-compatible automotive Ethernet Switch SoCs offering a scalable solution for all vehicle applications.

All SJA1110 variants come with hardware-assisted security and safety capabilities, multi-gigabit SGMII interfaces and the latest AVB and TSN standards.

SJA1105TELY Ethernet Switch, AEC-Q100, 1GBPS, LFBGA

The SJA1105 is an IEEE 802.3-compliant 5-port automotive Ethernet switch. Each of the five ports can be individually configured to operate in MII, RMII and RGMII modes. This arrangement provides the flexibility to connect a mix of switches, microprocessors and PHY devices. It can be used in various automotive scenarios such as gateway applications, body domain controllers or for interconnecting multiple ECUs in a daisy chain.

For more information about **Industrial Control and Automation**, check out our dedicated web page.



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