Application Brief

Designing Functionally Safe and AI Enabled Robotics Systems with TI Processors

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Introduction

Robotic systems are becoming increasingly complex, requiring advanced processing platforms capable of operating intelligently, safely, and in real time. Whether deployed in AMRs (autonomous mobile robots), collaborative industrial robots, or humanoid platforms, robotics applications of today demand a combination of high-performance compute, deterministic real-time control, functional safety, edge AI acceleration, and secure execution. These requirements impose unique challenges on system architects, who must integrate diverse computing domains—application logic, AI inference, safety-critical control, and sensor fusion—within a unified and cost-effective hardware platform. The need for concurrent processing of AI workloads, low-latency control loops, and compliance with stringent safety standards such as IEC 61508 and ISO 26262 calls for a purpose-built design.

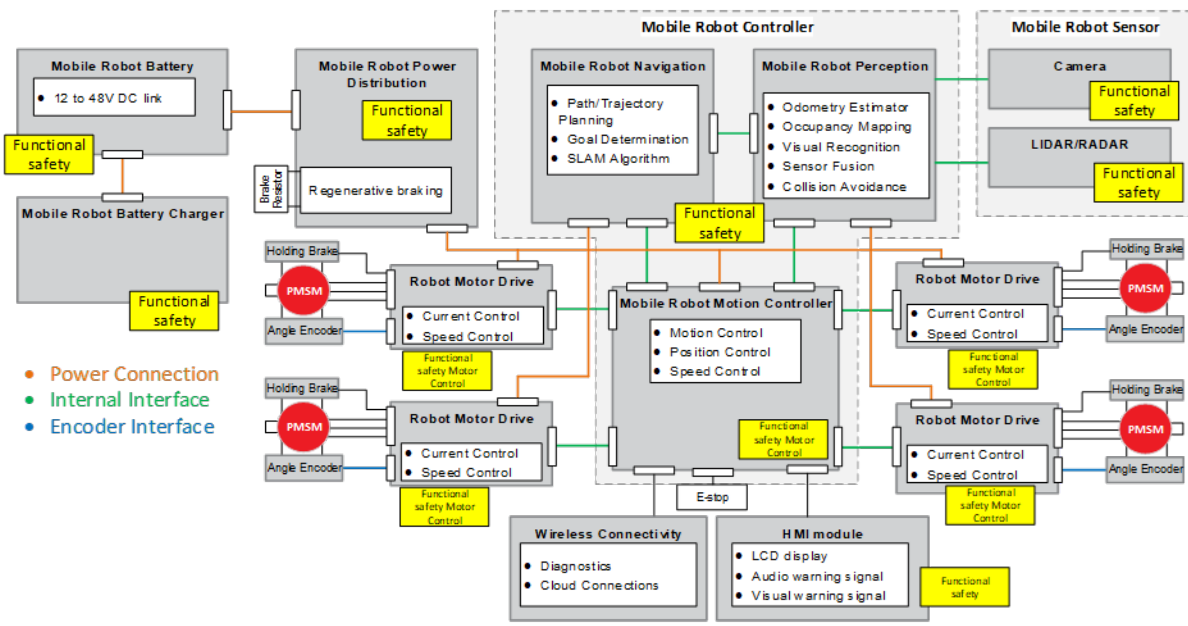

Figure 1. System Block Diagram of Mobile Robot Enabling Functional Safety

Functional Safety

Functional safety is a foundational requirement in many robotics applications, especially those that operate in close proximity to humans. Processors must be selected with functional safety in mind, featuring diagnostics such as voltage and temperature monitors, ECC-protected SRAM, and power and clock domain separation. Another necessary feature is FFI (Freedom from Interference), allowing safety mechanisms to remain active even if the application domain experiences failure. The device must meet industrial-grade safety certifications including IEC 61508 SIL-3 and ISO 26262 ASIL-D, making them designed for safety-critical industrial and autonomous robots, as shown in Figure 1. The hardware also must accompany firmware libraries, which are required for implementing and validating safety functions across runtime conditions.

Efficiency

Robotic systems must also deliver high-throughput, low-latency sensor fusion from multiple modalities such as vision, LiDAR, and radar to complete program functions safely in real time environments. Multiple cores and hardware accelerators are often needed to handle the multiple processes to handle the data. The various cores manage sensor I/O, feedback control, and motor actuation with deterministic latency, while the hardware accelerators process video, imaging, and AI data concurrently. SoCs that feature built-in support for high-bandwidth sensor interfaces such as CSI-2, CAN-FD, and Ethernet, and include internal memory and high-speed interconnects facilitate efficient data movement and fusion. This architecture verifies real-time performance for mission-critical control loops while offloading intensive AI and vision processing to dedicated subsystems.

Edge AI Studio

Edge AI is central to modern robotics, enabling autonomous systems to detect, identify, and react to dynamic environments without relying on the cloud. This supports the execution of multiple neural networks in parallel—essential for tasks such as object detection, semantic segmentation, and SLAM. TI's Edge AI Studio simplifies model development, benchmarking, and deployment, while the TI Model Zoo provides a suite of pre- optimized networks such as YOLO, MobileNet, and ResNet, ready for retraining on application-specific data. This allows robotics developers to quickly iterate and deploy intelligence directly at the edge.

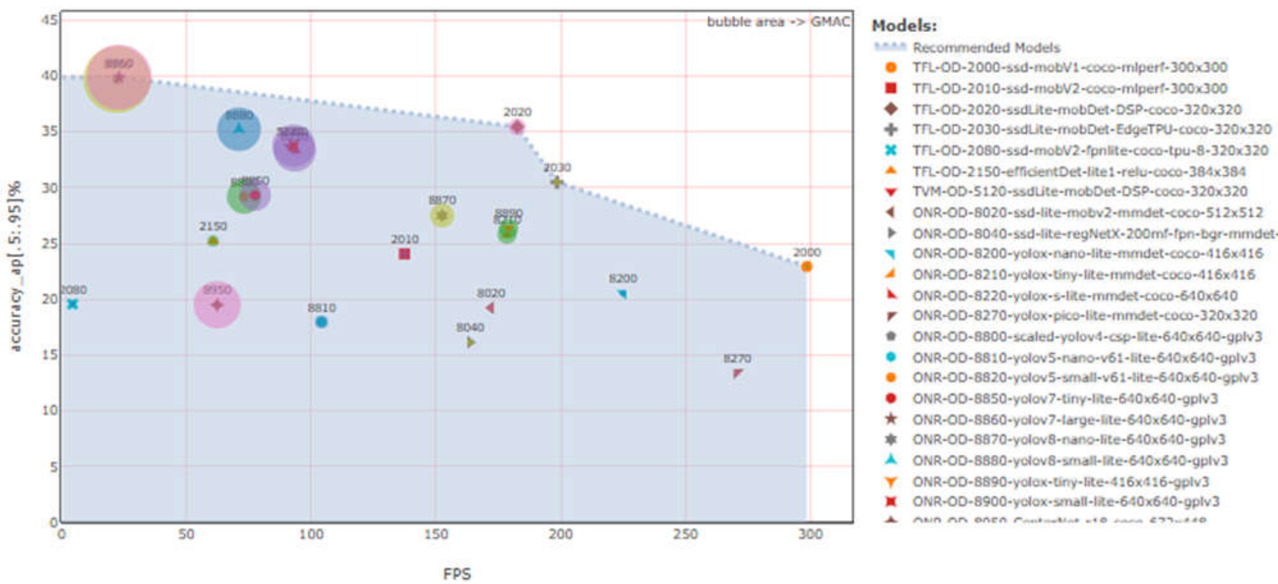

Figure 2. Edge AI Studio

Security

Security is another essential pillar for robotic systems, particularly in applications involving human collaboration, cloud connectivity, or proprietary data. The processors must have a secure boot process, hardware root of trust, and memory protection units that support secure data handling and firmware validation. Arm TrustZone technology provides an additional layer of isolation between secure and non-secure operations. These features are critical in preventing unauthorized access, firmware tampering, and data leakage, which verifies the integrity and safety of robotic operations across commercial and industrial environments.

Architecture

The TDA4 family of processors addresses these system-level challenges through a highly integrated and safety-optimized system-on-chip (SoC) architecture. TI's processor platform is designed for robotics due to the heterogeneous multicore structure. The platform features high-performance Arm® Cortex®-A72 or A53 application processors for operating systems and application tasks, real-time Arm Cortex-R5F cores within a dedicated and isolated MCU island for deterministic control, and TI's next-generation C7x digital signal processor (DSP) with a matrix multiplication accelerator for signal and AI processing to deliver up to 32 TOPS of AI performance. These compute elements are complemented by hardware accelerators for imaging, vision preprocessing, and deep learning inference. This architecture enables developers to isolate safety-critical operations from general-purpose tasks, reducing the need for external safety microcontrollers and simplifying design. TI also invests heavily in security, ensuring the integrity, authenticity, and confidentiality of systems using the devices. All TDA4x devices are HS-FS (High Secure - Field Securable) and contain security-specific IP such as HSM (hardware security modules) and cryptographic accelerators. Features such as Secure Boot, TEE (trusted execution environment), and secure debug support allow customers to trust in products to do the task at hand.

Software

To enable fast time to market, TI offers a comprehensive and unified software development environment across the TDA4 family. This includes open-source and real-time OS support such as FreeRTOS and Linux, with consistent APIs and middleware across devices. Developers can use the TI Software Diagnostic Library for safety mechanisms and take advantage of real-time IPC libraries for seamless communication between cores. In addition, partnerships with QNX, Green Hills, and Wittenstein provide access to certified RTOS environments like SafeRTOS and INTEGRITY. TI also contributes to the upstream Linux kernel, making sure there is long-term support and maintainability for robotics systems based on TI processors.

Proteus

The TDA4VM is used in Amazon's Proteus autonomous mobile robot to navigate warehouse environments safely alongside humans. Proteus performs perception, path planning, and actuation in real time using multiple camera feeds and sensors. The integrated safety infrastructure, AI acceleration, and high-performance compute of the TDA4 processor enable this level of autonomy without requiring external control or compute units which demonstrates the scalability and robustness of TI's processor platform for advanced robotics applications. Read the *Designing Proteus: Amazon's first autonomous mobile robot* case study to learn more about the TDA4VM in the Amazon Proteus.

Conclusion

In summary, the TDA4 family of processors provide a system-ready platform for robotics developers seeking to build safe, intelligent, and real-time robotic systems. With integrated functional safety, real-time control, edge AI acceleration, secure processing, and a unified development environment, these SoCs address the full stack of challenges in modern robotics. With TI's extensive experience, scalable architecture, and strong software ecosystem, developers can design functionally safe, AI enabled, and robust robotics systems. To evaluate a robotic design, visit TI.com and order a processor EVM today.

References

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