Chapter 7

# A Mixed-Criticality Integration in Cyber-Physical Systems:
## A Heterogeneous Time-Triggered Architecture on a Hybrid SoC Platform

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## ABSTRACT

*A Cyber-Physical System (CPS) describes a system or a system-of-systems closely and actively coupled with environment. It comprises the digital intelligence system, a co-dependent physical system (i.e., electrical, mechanical) and the system environment. Since the beginning of modern computer systems integration was ever present challenge, from the huge single room computers to the IoT. Today applications interleave and build larger systems with different system requirements and properties. Implementation of safety critical applications together with non-critical applications within the same platform is almost inevitable in modern industrial systems. This article provides a retrospective overview of the major integration challenges and the current problems in mixed-criticality environments. Finally, it provides an insight in a hardware solution which creates deterministic platform for mixed-criticality applications.*

## 1. INTRODUCTION

The topic of cyber-physical systems (CPS) is an interdisciplinary subject that connects computer engineering and computer science with other disciplines like electrical, mechanical, chemical and bio-engineering. In essence, it provides a shell for the system design which binds digital and physical world in a compact methodological form. It provides a better understanding of the system from various perspectives, it increases time to market and overall efficiency of the product. This concept was crafted

as a response to the increasingly complex structure of modern systems. The advantages of computer driven physical systems were recognized in the early stages of the computer development timeline. The physical systems controlled by a computer would reach their physical limits much rapidly, they were getting upgraded more frequently and in conclusion getting more complex. The initial approach of the system design was highly segregated in means of engineering disciplines. For the most part physical components of a system would be designed according to the techniques and methods used in a specific discipline, and then interfaced with a specific computer system. This approach provided a relatively clean design methodology, but as the systems got more complex it was more difficult to ensure that the functional properties of the system conform to the system specifications and regulatory guidelines. The work presented in this chapter reflects on the challenges present in the domain of mixed-criticality systems and the overcoming need for seamless integration. It also offers a viable solution based on a time-triggered architecture implemented on a hybrid system-on-a-chip platform. This novel approach to create a modular configurable deterministic hardware architecture combats core problems of industrial computer systems, where safety critical applications interact and operate under same conditions as non-critical applications. This closely coupled relation is extremely complicated on a commercial off the shelf (COTS) hardware. It is also highly expensive in terms power consumption, performance and utilization. The presented architecture enables clear separation between different tasks in space and time without performance loss. The extended plans foresee a tool chain integration to increase the ability to build an application directly from hardware level up.

## 1.1 Chapter Outline

This chapter provides a short reflection on mixed-criticality integration in cyber-physical systems. It explores the challenges and basic properties for the seamless integration not only user applications, but also underlying platform components, hardware, software and the physical environment. Section 1 gives a short introduction in cyber-physical systems and mixed-criticality integration, in particular Section 1.1 gives a short historical summary of the cyber-physical systems and turning points that lead to the modern state of CPS. Also, Section 1.3 gives an overview of the major challenges or objectives for mixed-criticality integration. Further, Section 2 gives a brief introduction in the background knowledge on the relevant topics. First, Section 2.1 describes spatial and temporal isolation as vital properties in the design of systems for mixed-critical integration. Section 2.2 introduces an innovative computer architecture that combines a hard-coded computer processing units with an FPGA device on a single chip, it is a synergy of different approaches and a product of merging knowledge from two different directions. Further, Section 2.3 describes an architecture built for mixed-criticality integration based on time-triggered communication and FPGA technology. Section 3 provides a description of the architecture that merges technologies described in Sections 2.2 and 2.3. Section 4 offers a brief overlook on the presented architecture and its ability to meet the challenges described in Section 1.3. The ability of the architecture to resolve practical issues has been shortly visited in Section 4.1. Finally, Sections 5 and 6 provide future work potentials and closing thoughts.

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