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Energy Efficient Data Acquisition and Processing Architectures Using ARM Cortex M Series



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Abstract

This chapter presents an in-depth exploration of energy-efficient data acquisition and processing architectures leveraging ARM Cortex-M series microcontrollers for smart embedded systems. Emphasis is placed on advanced methodologies such as low-power sensor interfacing, optimized analog-to-digital conversion techniques, and peripheral autonomy with Direct Memory Access (DMA) to minimize energy consumption while maintaining high system responsiveness. Key design strategies including time-slot allocation for periodic sensing, event-driven sampling, and cross-sensor interrupt management are analyzed for their effectiveness in reducing processor wake-ups and balancing energy usage across multi-sensor platforms. Detailed discussions on hardware-software co-optimization underscore the critical role of integrating microcontroller capabilities with intelligent firmware design to achieve scalable and sustainable IoT solutions. Performance evaluation frameworks and benchmarking metrics are also addressed to provide comprehensive guidelines for developers targeting ultra-low-power real-time applications. The insights offered herein aim to advance the state-of-the-art in low-energy embedded sensing, contributing to longer device lifetimes and more efficient edge intelligence.

Keywords: Energy-efficient data acquisition, ARM Cortex-M microcontrollers, low-power sensing, DMA, time-slot allocation, interrupt management

Introduction

Energy efficiency remains a paramount concern in the design and deployment of embedded systems, particularly those aimed at Internet of Things (IoT) applications, wearable devices, and remote monitoring systems [1]. The ARM Cortex-M series microcontrollers, renowned for their balance of computational performance and low power consumption, have become a cornerstone in the development of such systems [2]. These microcontrollers integrate advanced architectural features and energy-saving modes that, when combined with intelligent data acquisition and processing strategies, enable prolonged operational lifetimes even under stringent power budgets [3]. The challenge lies in optimizing every stage of data acquisition—from sensor interfacing to signal conversion and processing—while minimizing energy expenditure without compromising

system responsiveness or data integrity [4]. This chapter explores these optimization strategies, emphasizing how hardware-software co-design can be leveraged to create highly efficient embedded architectures suited for real-time, low-power applications [5].

Data acquisition constitutes the initial and critical phase of the embedded sensing pipeline, directly influencing downstream processing and communication efficiency [6]. Sensors embedded in low-power devices often operate under intermittent or event-driven conditions, requiring adaptive and context-aware sampling methodologies [7]. Such methods ensure that energy consumption is curtailed during idle periods while guaranteeing accurate and timely data collection during active intervals. The ARM Cortex-M microcontrollers support diverse peripheral interfaces and configurable power modes that facilitate dynamic adjustment of sensor activity [8]. Techniques such as duty cycling, event-triggered wake-up, and peripheral autonomy enable sensors and microcontrollers to operate collaboratively, minimizing unnecessary CPU engagement, employing optimized analog-to-digital conversion schemes [9]. Including low-power ADC modes and asynchronous sampling, significantly reduces power consumption during signal digitization, a typically energy-intensive task [10].