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ANALYSIS OF MODERN ANALOG-TO-DIGITAL CONVERSION METHODS FOR INFORMATION PROCESSING SYSTEMS

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Annotation. *The accuracy and efficiency of modern information processing systems depend significantly on the quality of analog-to-digital conversion. Since most physical processes generate analog signals, their transformation into digital form is a critical stage in data acquisition and processing. This paper presents an analysis of modern analog-to-digital conversion methods used in information processing systems. The operational principles, advantages, limitations, and application areas of the most common ADC architectures are examined. A comparative assessment of successive approximation, flash, sigma-delta, pipeline, and tracking converters is performed. Based on the analysis, recommendations for selecting appropriate ADC architectures for different information processing tasks are proposed.*

Keywords: *analog-to-digital converter, information processing systems, ADC architecture, signal acquisition, successive approximation ADC, sigma-delta ADC, digital signal processing.*

INTRODUCTION

The continuous advancement of information technologies, digital communication systems, intelligent measurement devices, and automated control systems has significantly increased the importance of efficient analog-to-digital conversion [1]. In contemporary information processing systems, the primary source of information is frequently represented by analog physical quantities generated by sensors, transducers, and measurement channels. Consequently, the process of transforming analog signals into digital form represents one of the most critical stages in the overall information processing chain.

The quality of analog-to-digital conversion directly affects the accuracy of subsequent signal processing, parameter estimation, pattern recognition, and decision-making procedures. Conversion errors introduced at the data acquisition stage cannot generally be eliminated through further digital processing. Therefore, the selection of an appropriate analog-to-digital converter architecture constitutes a fundamental design problem in modern information systems [2].

Recent developments in semiconductor technologies have led to the emergence of numerous converter architectures characterized by different trade-offs between resolution, conversion speed, power consumption, dynamic range, and implementation complexity. As a result, a systematic analysis of modern conversion methods is necessary to determine the most suitable architecture for specific application domains.

REQUIREMENTS FOR ANALOG-TO-DIGITAL CONVERSION IN INFORMATION PROCESSING SYSTEMS

Information processing systems operating in scientific instrumentation, industrial automation, telecommunications, biomedical engineering, and aerospace applications exhibit substantially different requirements regarding data acquisition performance. However, several key parameters remain common to all applications [3].

Among the most significant characteristics are conversion accuracy, effective number of bits, signal-to-noise ratio, dynamic range, conversion latency, sampling frequency, and power efficiency. In practical applications, the improvement of one parameter is often accompanied by the degradation of another. Consequently, converter selection must be based on a compromise between conflicting performance requirements.

For example, high-speed communication systems require sampling rates reaching several gigasamples per second, whereas precision measurement systems prioritize resolution and noise suppression over conversion speed. This diversity of requirements explains the coexistence of multiple analog-to-digital converter architectures in modern electronic systems [4].

COMPARATIVE ANALYSIS OF MODERN ADC ARCHITECTURES

Among the converter architectures currently employed in information processing systems, flash, successive approximation, sigma-delta, pipeline, and tracking converters occupy dominant positions.

Flash converters provide the shortest conversion time due to the parallel implementation of threshold comparison operations. Their architecture enables real-time processing of broadband signals and ultra-high-frequency data streams. However, the exponential increase in hardware complexity with increasing resolution significantly restricts their application to systems requiring moderate accuracy and extremely high sampling rates [5].

Pipeline converters represent a compromise between conversion speed and resolution. Their multistage structure allows high-throughput processing while maintaining acceptable accuracy. Owing to these properties, pipeline architectures are extensively used in digital communication systems, radar equipment, and high-definition video processing devices [6].

Sigma-delta converters employ oversampling and digital filtering techniques to achieve exceptionally high resolution and superior noise suppression characteristics. The redistribution of quantization noise outside the useful signal band makes these converters particularly attractive for instrumentation, biomedical electronics, and high-fidelity audio systems. Nevertheless, the relatively low conversion speed limits their applicability in broadband signal processing applications [7].

Tracking converters possess adaptive properties and continuously monitor variations of the input signal. Their operation is particularly efficient when processing slowly varying signals characterized by high temporal correlation between successive samples. However, the relatively limited conversion speed and susceptibility to rapid signal transitions have reduced their prevalence in contemporary integrated circuits.

The analysis indicates that successive approximation register (SAR) converters currently occupy a unique position among modern architectures. Advances in CMOS technologies have enabled significant improvements in their conversion speed while preserving high resolution and low power consumption. As a result, SAR converters have become the dominant solution for embedded information processing systems, wireless sensor networks, industrial monitoring platforms, and portable electronic devices.

DISCUSSION

The conducted analysis demonstrates that no universal analog-to-digital converter architecture exists for all classes of information processing systems. Instead, the selection process should be based on the operational characteristics of the target application, signal bandwidth, required dynamic range, and energy constraints.

From the perspective of overall efficiency, successive approximation architectures provide the most balanced combination of technical and economic characteristics. Their moderate hardware complexity, high conversion accuracy, low energy consumption, and scalability make them particularly attractive for contemporary digital systems.

At the same time, applications involving ultra-high-speed signal acquisition continue to rely on flash and pipeline architectures, whereas precision instrumentation systems increasingly employ sigma-delta converters due to their superior metrological characteristics.

CONCLUSION

The performed investigation confirms that analog-to-digital conversion remains a key technological component of modern information processing systems. The characteristics of the selected converter architecture significantly influence system accuracy, reliability, processing efficiency, and implementation cost.

Comparative analysis of contemporary conversion methods indicates that flash converters provide maximum speed, sigma-delta architectures ensure the highest measurement accuracy, and pipeline converters effectively support broadband signal processing applications. However, considering the aggregate of performance indicators, successive approximation register converters currently represent the most versatile and technologically justified solution for a wide range of information processing tasks.

Future research should focus on adaptive conversion techniques, machine-learning-assisted calibration methods, and the development of hybrid converter architectures capable of simultaneously achieving high speed, high resolution, and low power consumption.

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