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Beyond Binary Choices: A Multi-dimensional TOPSIS Evaluation of Analogue and Digital Signal Processing Technologies

*** Nathiya Murali, Sathiyaraj Chinnasamy, Devipriya Mani, M. Ramachandran**
REST Labs, Kaveripattinam, Krishnagiri, Tamilnadu, India,
Corresponding Author Email:* **nathiyamurali6775@gmail.com

Abstract: *This study employs the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) method to compare analogue and digital signal processing across multiple criteria: accuracy, flexibility, complexity, and cost. The research aims to provide a comprehensive analysis of the strengths and weaknesses of both processing methods to guide decision-making in various applications. The study reveals that analogue processing excels in signal conversion and implementation, while digital processing demonstrates superiority in flexibility and signal integrity. The analysis highlights the inherent trade-offs between performance metrics, emphasizing that the choice between analogue and digital processing should be tailored to specific application requirements. Using equal weightings for all criteria, the TOPSIS analysis provides a balanced evaluation of both processing methods. The results indicate that implementation ranks highest in importance, followed by power consumption and representation. Signal integrity ranks lowest, suggesting an area for potential improvement in both analogue and digital domains. The research underscores the complexity of digital processing, which is balanced by its superior flexibility and accuracy. Cost-effectiveness varies between the two methods, necessitating case-by-case evaluation. The study also highlights the significance of power consumption in modern signal processing applications, particularly in energy-constrained environments. This analysis offers a nuanced understanding of analogue and digital signal processing methods, emphasizing the importance of considering multiple criteria in decision-making. It suggests that future developments should focus on improving signal integrity and reducing complexity without sacrificing performance. The findings indicate that integrating the strengths of both analogue and digital processing may lead to more efficient and effective signal processing solutions across various applications.*

Keywords: *Analogue signal processing, Digital signal processing, Signal integrity, Power consumption, Implementation, Flexibility, Complexity, Multi-criteria decision making and Signal conversion.*

1. INTRODUCTION

Based on digital signal processing methods, signals must be measured at discrete time intervals and represented as sequences of 1s and 0s. In nature, signals are typically continuous and infinite, such as air pressure waves from speech. These natural signals are converted into analog electrical signals through a transformer. To create a digital representation of an analog signal or to produce an analog output from a digital signal, the inverse process must be applied. The accuracy of the analog signal representation depends on the measurement levels used, the sampling rate, and the requirements for bandwidth and system cost [1]. In the context of body area networks, an intelligent sensor node plays a crucial role. It monitors physiological parameters such as ECG, EEG, or temperature using a sensor. The sensor node itself handles local signal processing, which can provide instant feedback, implement closed-loop systems, or reduce data storage requirements. This approach enhances exchangeability and extends operational life. The core component of the sensor node is the signal processor. These nodes are designed to be small, easy to wear, and powered by batteries with limited energy. Historically, battery capacity for a given size has doubled every 5 to 20 years. A comparison of this nature inherently involves several high-level assumptions, and it's somewhat obvious that specialized circuits often outperform standard ones. Nevertheless, this fact is effectively confirmed here. Furthermore, even when relaxing some assumptions, the analog approach remains competitive and, in many cases, preferable when compared to the digital domain [2]. Digital representation begins by sampling the analog signal, which makes the representation distinct. This can be achieved using time-based models. The signal is sampled and converted into a finite number of bits. Traditionally, these functions—sampling the continuous time input and quantizing it to minimize information loss—are considered separately. A scale is designed to represent samples as accurately as possible, within a limited number of usable bits. This article aims to review the interdependency between these functions, a scale is designed to represent samples as precisely as possible, within a limited number of usable bits within a system constrained by the available number of bits [3]. In time multiplexing, the input channels are shifted sequentially according to the multiplexing scheme. However, if one channel is changed, information from other channels will not be available. Therefore, the effective sampling rate for each channel is the ADC sampling rate divided by the number of channels. As the number of channels increases, the effective sampling rate per channel decreases, making this approach less desirable. In frequency multiplexing, the process involves converting analog signals so that they can occupy separate frequency bands together. These modulated signals are then digitized. However, a major drawback is that the required ADC sampling rate, which significantly impacts power consumption, increases linearly with the number of channels. As an alternative widely used in compressed sensing (CS) systems, we propose an approach involving spatial signal modeling, using blind source separation (BSS) and sparse reconstruction methods. This method allows for digitizing channel inputs with unknown frequencies using sinusoids. We consider the problem of quantizing these inputs with a single ADC or quantize system, Focuses on switched-capacitor (SC)-based sample-and-hold (S/H) circuits that implement a mixed-signal module. Such systems perform A/D conversion using discrete time functions in the analog domain [4]. Analog integrated circuits offer many advantages, but their digital counterparts often excel in speed, power dissipation, and silicon area efficiency. Digital circuits typically require programming capabilities, making them the preferred choice in many scenarios. Digital signal processors or microprocessors, for instance, provide significant flexibility since their functionality is determined through software development. Recent studies have led to the creation of programmable analog circuits, Digital FPGAs can be seen as the analog equivalent. Algorithmically programmable analog chips based on cellular neural network (CNN) operation have also been introduced. This paper describes an analog microprocessor (AµP) that runs software programs and can be considered the analog equivalent of a digital microprocessor [5]. Therefore, CMOS processes are usually optimized for digital circuitry needs. In essence, CMOS technologies enhance digital switching speed, lower supply voltages, and reduce transistor geometry to maximize packing density. These advancements push the information processing frequency into the gigahertz range. As a result, there is a growing demand to integrate digital, analog, and mixed-signal circuits on a single chip (system-on-chip). This integration is driven by companies' efforts to reduce costs, increase productivity, and develop low-power, compact devices. State-of-the-art digital CMOS technologies now encompass analog components as well. Integrating mixed-signal circuits presents numerous challenges. Emerging CMOS technologies are reducing feature sizes, leading to thinner transistor gate oxides, which in turn lowers system voltages. This reduction impacts the performance of analog and mixed-signal circuits negatively, as transistors operate at non-optimal points, causing leakage currents through the transistor gates. This issue creates a dilemma, as it limits input voltage swings and affects analog voltage linearity, ultimately complicating signal processing [6]. Radiation hardening and BER (Bit Error Rate) reduction are crucial aspects of designing data converters, but they present significant challenges. Radiation effects, such as single event effects (SEE), Single-event transitions and single-event offsets can greatly reduce the performance of data converters. Radiation hardening techniques typically involve architectural modifications and extensive simulations, including the use of modified SPICE models and detailed device state simulations. Consequently, architecture-specific radiation hardening and BER reduction techniques for data converters are highly desirable. High-level modeling and simulation methods facilitate faster verification of circuit designs by enabling detailed device and circuit block simulations. These techniques also help in creating data converters that are testable, reusable, and incorporate robust design practices [7]. It seems like you're discussing the impact of symbolic hypotheses on neural information processing, particularly how varying firing rates affect information transfer within neural systems. Theoretical models suggest that neural systems evolve to enhance their information transfer rates, potentially allowing different brain regions to process signals differently. This coding problem has garnered significant interest among researchers studying neural dynamics and information processing. Attractor positions are distinct for each firing location and may result in observable alterations. Processing information involves transitioning through intermediate positions, known as half-level jumps. This approach maximizes the detection of transition points in neurons, nearing theoretical optimality. Enhanced identification of indices significantly benefits information encoding, crucial for brain-machine interfaces in real-time applications [8]. Reducing capacitance and operating voltage offers speed and power advantages. However, it also lowers intrinsic device gain and necessitates changes in analog designs for smaller scale processes. As a result, analog components in mixed-signal systems consume more power and area, increasing design costs compared to digital counterparts. While digital circuits benefit from scaling, achieving similar benefits in analog circuits proves costly. This paper discusses a technique for flash analog-to-digital converters (ADCs) to address scalability challenges in future digital CMOS processes [9]. A digital-to-analog converter plays a crucial role as it translates digital information into analog signals. Meeting diverse frequency requirements and demanding high resolution, it operates at high speeds and with precision. While time-domain characteristics are critical, many operations are performed in the frequency domain. Parameters such as spurious-free dynamic range (SFDR), integral median deviation, signal-to-noise ratio, multitoned power ratio, and signal-to-noise and distortion ratio are used to assess its performance. Static characteristics can be defined as fixed or unchanging traits, typically represented by stable output values from a converter. These traits remain consistent regardless of operational conditions. Dynamic characteristics, on the other hand, involve properties that vary over time or with changing conditions. These can include responses to disturbances, transient behaviors, and other dynamic aspects like response time curves. In telecommunications applications, the quality of a converter is often judged by its dynamic performance, which reflects how well it adapts to changing conditions and maintains stability during operations [10]. Neuroscientists studying the decoding of neural activity and spike detection aim to understand how the brain processes information. This understanding is crucial for developing neuroprostheses that rely on the function of single neuronal units, essential for medical applications. Moreover, both fields face the challenge of recording from large populations of neurons (ranging from tens to thousands), necessitating advancements in wireless data transmission to manage increasing demands. Chip-based spike detection emerges as a viable solution to reduce on-chip data before transmission, addressing communication bandwidth and power constraints [11]. Cooperative Analog-Digital Signal Processing (CADSP) is an innovative design methodology that integrates both analog and digital domains to enhance computational performance. Traditionally, analog processing (ASP) has been employed primarily for front-end tasks like amplification and initial data manipulation, while digital processing (DSP) handles more complex mathematical operations. By redefining the boundary between these processing domains, CADSP aims to achieve significant savings in power consumption and area utilization. For instance, leveraging subthreshold transistors in digital circuits allows for implementing mathematical operations with a minimal number of devices, thus drastically reducing overall current consumption. This approach capitalizes on the unique characteristics of digital circuits to achieve efficient computation while maintaining performance standards [12]. In the realm of emerging Nano electronic technologies, single electronics stands out as a prominent approach. This field involves the manipulation and control of electrons at a single or small number scale. At its core, single electronics relies on Coulomb confinement, a principle initially observed and explored by Gored. Constructing single-electron circuits is known for its high cost and time-intensive nature, prompting the development of Computer-Aided Design (CAD) tools and simulation techniques tailored for studying these circuits [13]. These signals typically manifest as voltage, current, or electrical characteristics like capacitance or inductance upon their initial perception. Subsequently, they undergo conversion into digital signals and are processed in successive stages. However, various electrical circuits are typically necessary for different sizes of analog signals. For instance, analog-to-digital converters (ADCs) are utilized for voltage conversion to digital form, while capacitive digital converters (CDCs) are specifically designed for converting capacitance into digital format. Occasionally, both converters can be integrated within a sensing system, resulting in significantly reduced power consumption [14]. Advantages over analog signal processing circuits include speed, lower power dissipation, and reduced area utilization compared to their digital counterparts. These benefits make them appealing to designers. Developments in general-purpose analog circuits, such as analog processors and Field-Programmable Analog Arrays, further enhance their versatility. These devices operate either continuously or in sample data mode, with programmability based on configurable arrays of cells. This allows processing algorithms to be implemented directly in hardware by establishing signal paths within the device [15].

2. MATERIALS AND METHOD

Processing Method: Processing techniques, billing factors, and usage information, which may include device events, service provider data, and/or data received from the application, specify the format or method of transmission.

Power Consumption: In electrical engineering Power consumption refers to the amount of electrical energy used per unit time. It is typically measured in watts or kilowatts. The energy consumed by equipment is generally higher than the necessary amount.

Signal Conversion: Signal conversion involves transforming a signal from one device to another to enable further processing. This process ensures that the measurement or output signal meets the input specifications of the receiving device. If the signal does not meet these specifications, modifications are necessary.

Signal Integrity: Ensuring efficient operation of the PCB relies significantly on signal integrity (SI). Essentially, it involves maintaining the signal's original waveform characteristics without any distortion, ensuring the receiver gets a clear and undistorted signal.

Implementation: Implementation involves applying concepts in real-world scenarios and using resources through established policies and procedures. It entails planning with the goal of transforming ideas and taking deliberate action. It focuses on project execution, addressing both the "how" and the "what."

Representation: The act of representation can be carried out under certain conditions involving words, characters, symbols, or similar elements. It can be an expression or designation by an individual, group, business entity, or a state agent, deputy, or representative, involving actions or speech on their behalf.

Accuracy: The state or quality of being true, correct, or accurate refers to the absence of errors or imperfections. In chemistry and physics, accuracy signifies the degree to which a given measurement aligns with a fixed value.

Flexibility: Flexibility is a natural characteristic of body tissues, allows a joint or group of joints to move through their full range of motion without injury.

Complexity: This term typically denotes an entity composed of numerous components. It signifies that there are multiple elements involved. These elements interact in various ways, ultimately resulting in an expression that exceeds the sum of its individual parts.

Cost: Expenditure refers to purchases of goods, services, and other operational necessities within a business context. The method used to ascertain the cost of components is crucial. Costing represents a specific and regulated technique, akin to other procedural processes

TOPSIS Method: Decision-making is crucial in both personal and commercial contexts. While multi-criteria decision-making methods offer tools for decision-makers, they differ based on assumptions and grounded theory. Therefore, selecting the appropriate method rather than just making a decision is vital. Among the most commonly used methods is TOPSIS, which has garnered attention from researchers leading to various enhanced versions. This study focuses on TOPSIS, examining its conventional application through simulation to identify its theoretical foundations and contribute to methodological advancements [16]. The TOPSIS method is widely used for multi-criteria decision making with real-valued data. However, dealing with fuzzy ratings poses challenges, as accurate estimates of alternative rankings based on local criteria can be elusive. Many extensions of TOPSIS in literature address these challenges but often overlook comprehensive solutions for handling fuzzy values. Existing approaches typically involve defuzzification of fuzzy decision matrices, which can lead to information loss and erroneous outcomes. This paper introduces a novel fuzzy extension method for TOPSIS that overcomes these limitations by directly addressing fuzzy values without resorting to defuzzification. Our approach modifies the weighted sums of criteria to measure the distance of alternatives from optimal solutions, offering a promising alternative to existing methods [17]. Decision-making involves selecting the best alternative from all available options. In most cases, this process requires evaluating alternatives against multiple criteria, which are often mutually exclusive. Therefore, it's usually impossible to satisfy all criteria simultaneously. To address this challenge, decision makers often turn to Multi-Criteria Decision Making methods. One such method, proposed by Hwang and Yoon, is the technique of order of preference by similarity to the ideal solution (TOPSIS). This technique selects the alternative with the shortest geometric distance to the positive ideal solution and the farthest geometric distance from the negative ideal solution. [18]. A novel approach is introduced for robot selection using the Fuzzy TOPSIS method. This method evaluates various alternatives and subjective criteria, which are assessed using linguistic scales and weights represented by ambiguous linguistic terms. Objective values are established by converting these linguistic evaluations into dimensionless symbols. The compatibility between criteria values and linguistic evaluations is determined objectively. Weighted ratings for each alternative are derived using arithmetic operations on ambiguous numbers. A comprehensive aggregation process smooths these weighted estimates and decomposes them to determine rank orders. Ideal and negative ideal solutions are used to calculate distances, which are then normalized to rank the alternatives. A numerical example illustrates the computational procedure of the proposed method [19]. In a modern economy, achieving productivity and income growth is crucial. Selecting the right machinery plays a pivotal role in global business survival and successful production. However, the increasing complexity of machine selection, compounded by conflicting criteria, presents challenges. To address this, a decision support system combining AHP and TOPSIS has been developed. This framework guides decision makers in selecting the most suitable machines. The research involves two main steps: firstly, analyzing criteria weights using AHP to identify key sectors and sub-sectors; secondly, ranking alternative machines using TOPSIS. This approach demonstrates a practical application of these methods to real-world problems [20]. The primary aim of this thesis is to achieve holistic integration by harmonizing the ideal of creation It proposes to improve the fuzzy technique for priority order by simulating the method of ideal solution (TOPSIS) for evaluating decision criteria and ranking alternatives. The methodology involves classifying criteria, Integrating the weights of criteria and sub-criteria and calculating performance values in a decision matrix. This model categorizes parameters as subjective or objective criteria. Subjective weights are determined using Fuzzy Analytic Hierarchy Process and entropy weighting methods, while objective weights are solved using these methods. Additionally, the integration weights are adjusted through interconnected measurements of both approaches [21]. Challenges such as fragmentation, fly rock, and cost in explosive operations must meet specific criteria. Previous detonations guide the search for optimal design alternatives, requiring simultaneous consideration of all criteria. Techniques such as the Technique for Order Preference by Similarity to Ideal Solution offer new multi-criteria decision-making approaches. Utilizing the TOPSIS method, current exploration focuses on blasting activities at Taj are Limestone Mine to identify the most effective explosive selection method. The heat produced during the explosive reaction and the resulting stress initiates new fractures. This not only releases the contents but also primarily energizes fragments of rock, resulting in Fly rock, defined as debris landing outside designated areas. Despite careful planning in explosive use, Fly rock incidents near populated areas are unfortunately common, leading to numerous injuries reported worldwide, particularly in open pit mine [22]. The initial common attribute among real numbers is identified first. Proof theory computes weights and determines the optimal solution, defining the negative ideal solution. A more advanced nonlinear modeling platform is then established, employing real-number weights. This approach is essential for intuitive decision-making in multi-attribute fuzzy set spaces. Methods for decision-making with ambiguous weights and intervals are explored. In this study, attributes and weights are both described as fuzzy values. The TOPSIS method is proposed for resolving decision-making problems with fuzzy-valued, multi-attribute data Initially, interval fuzzy attribute values are weighted according to interval value operation rules. Positive and negative solutions are identified based on the scoring function. Fuzzy value intervals are defined, and the distance from each scheme to the best and negative best solutions is calculated. Using the TOPSIS method, relative closeness degrees are calculated, followed by ranking the projects based on relative closeness degrees [23]. In their work on fuzzy TOPSIS, Triantaphyllo and Linn emphasize the importance of achieving smooth relative closeness among alternatives. They argue that using fuzzy weights and estimates fosters a nuanced closeness, essential for addressing complex decision-making scenarios. However, they highlight challenges stemming from arithmetic operations, which can distort and exaggerate the perception of intimacy between alternatives, thereby influencing the feasibility of their proposed solutions [24]. Generally, selecting the best employees is typically a complex and time-consuming process for organizations. Therefore, establishing a decision support system that incorporates a reliable criterion is crucial for facilitating this process efficiently. In this study, the (TOPSIS) method is proposed as an effective computational approach for employee selection. This method evaluates candidates based on criteria such as job responsibilities, work discipline, and quality of work and conduct, ultimately aiding top management in making well-informed decisions regarding employee selection [25]. In addressing Multi-Criteria Decision Analysis issues, a hybrid method integrating Ordered Weighted Average with the Technique for Order Preference by Similarity to Ideal Solution is proposed. Initially, the approach accommodates either a single decision maker or multiple DMs, allowing for diverse perspectives. TOPSIS is adapted to handle extreme points in both ideal and anti-ideal scenarios through redefined criteria. Furthermore, the study introduces three distinct OWA aggregation schemes tailored for TOPSIS applications. A practical numerical example illustrates the methodology, comparing outcomes across varied aggregation settings to validate the approach's efficacy under different conditions [26]. When utilized effectively, SWOT analysis serves as a solid framework for strategy development. However, it also has limitations in strategic decision-making. Traditional SWOT analysis fails to prioritize the importance of each factor in relation to proposed strategies, thereby not adequately measuring their impact. Consequently, it does not offer a robust methodology for assessing the validity of alternatives based on these factors. Moreover, the brief and general descriptions of individual factors in SWOT analysis further restrict its ability to comprehensively evaluate strategic decisions. To address these shortcomings, this study employs SWOT analysis alongside the TOPSIS technique, which ranks alternatives based on their similarity to the ideal solution, potentially enhancing strategic decision-making by identifying the optimal alternative among choices [27]. A smart city is an urban environment enhanced by ICT, aimed at improving residents' quality of life and urban infrastructure efficiency. It leverages technology to offer increasingly better services. Typically, a smart city integrates ICT-based facilities into its physical infrastructure, enhancing urban behaviors and capabilities. Scalability, both geographically and operationally, is essential to meet growing demands and adapt to evolving needs. The concept of a smart city has influenced government strategies worldwide, focusing on developing intelligent transportation, energy systems, and various public services to optimize urban life through effective and efficient use of technology [28]. Numerous mathematical programming models have been developed for solving project-selection problems.

However, in recent years, Multiple Criteria Decision Making methods have gained significant attention for evaluating proposals. Monty's research focuses on integrating multidimensional issues into the MCDM framework to enhance decision-making capabilities. One methodology explored in this research addresses project selection problems using the Fuzzy (AHP) and TOPSIS techniques, particularly in scenarios lacking qualitative criteria. The study evaluates investments using financial metrics such as net present value, rate of return and benefit-cost analysis within the AHP framework. It compares alternatives using four commonly employed methods, weighting each criterion and evaluating projects using the TOPSIS algorithm [29]. A decision-making system utilizing the TOPSIS method is proposed for selecting kindergartens, incorporating evaluation criteria such as kindergarten level, type, accreditation status, establishment date, class capacity, teacher-to-student ratio, academic achievements, tuition fees, and registration costs. This system aims to provide comprehensive information to parents, facilitating informed decisions through both examinations and a dedicated website. Furthermore, the website integrates geographical data to pinpoint the locations of reviewed kindergartens [30].

3. RESULTS AND DISCUSSION

TABLE 1. Analogue and Digital Single Processing

	Accuracy	**Flexibility**	**Complexity**	**Cost**
Processing Method	11.22	87.65	64.23	15.23
Power Consumption	33.44	91.21	67.95	23.51
Signal Conversion	66.15	52.32	45.23	89.35
Signal Integrity	19.24	94.25	62.52	98.99
Implementation	97.65	87.54	87.91	87.65
Representation	10	24	15	10

The table presents a comparative analysis of analogue and digital signal processing methods using the TOPSIS method across various criteria: accuracy, flexibility, complexity, and cost. Analogue processing demonstrates significant strengths in signal conversion and signal integrity, scoring 66.15 and 19.24, respectively. It excels in signal conversion due to its score of 66.15, surpassing digital processing in this criterion. However, digital processing shows higher scores in accuracy (11.22), flexibility (87.65), and complexity (64.23). It maintains a competitive edge in power consumption with a score of 33.44, compared to analogue's 91.21. Overall, the choice between analogue and digital methods should be tailored to specific needs, balancing trade-offs in performance metrics.

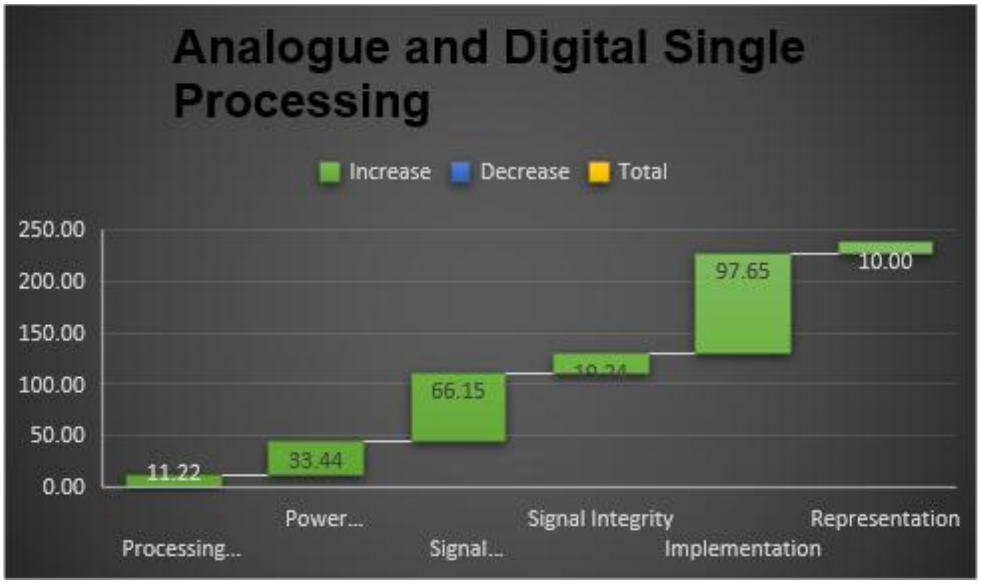

FIGURE 1. Analogue and Digital Single Processing

Figure 1 uses the TOPSIS method to compare analogue and digital single processing across accuracy, flexibility, complexity, and cost. Analogue processing excels in signal conversion (66.15) and signal integrity (19.24), while digital processing scores higher in accuracy (11.22), flexibility (87.65), and complexity (64.23), with varied cost implications.

TABLE 2. Normalized Data

	Accuracy	**Flexibility**	**Complexity**	**Cost**
Processing Method	0.0898	0.4628	0.4268	0.0938
Power Consumption	0.2675	0.4816	0.4515	0.1448
Signal Conversion	0.5292	0.2763	0.3005	0.5504
Signal Integrity	0.1539	0.4977	0.4154	0.6098
Implementation	0.7812	0.4623	0.5841	0.5400
Representation	0.0800	0.1267	0.0997	0.0616

Table 2 presents normalized data using the TOPSIS method for analogue and digital single processing. Analogue processing demonstrates strengths in signal conversion (0.5292) and implementation (0.7812), while digital processing excels in flexibility (0.4628) and signal integrity (0.4977). Both methods show comparable scores in complexity and cost, with slight advantages for digital processing in these criteria. These normalized values provide a clearer picture of relative performance across different metrics, aiding in decision-making based on specific operational priorities and constraints in analogue and digital signal processing applications.

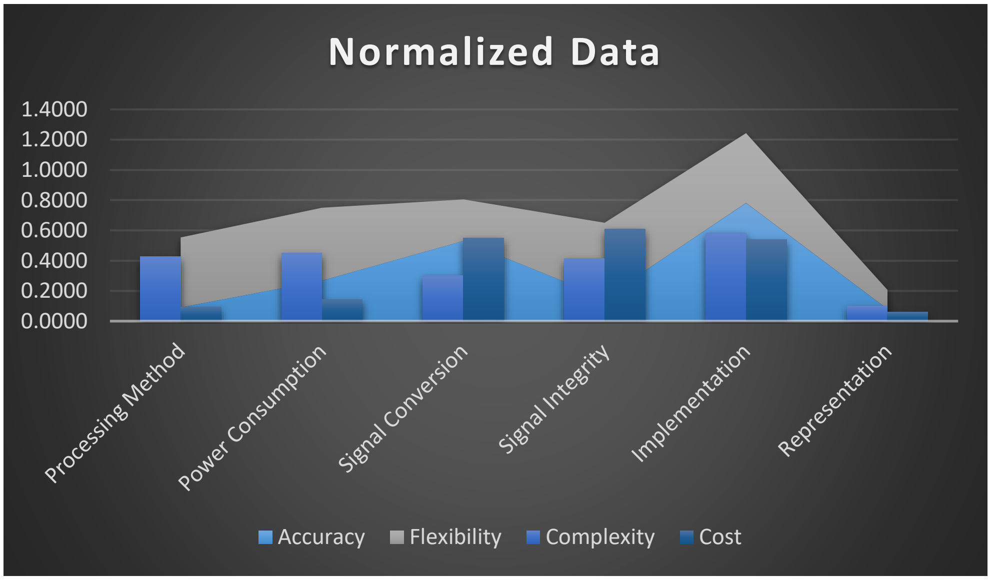

FIGURE 2. Normalized Data

Figure 2 uses the TOPSIS method to display normalized data for analogue and digital single processing across accuracy, flexibility, complexity, and cost. Analogue processing shows higher scores in signal conversion (0.5292) and implementation (0.7812), while digital processing excels in flexibility (0.4628) and signal integrity (0.4977).

TABLE 3. Weightages

weight			
0.25	0.25	0.25	0.25
0.25	0.25	0.25	0.25
0.25	0.25	0.25	0.25
0.25	0.25	0.25	0.25
0.25	0.25	0.25	0.25
0.25	0.25	0.25	0.25

Table 3 assigns equal weightages (0.25 each) using the TOPSIS method across criteria: accuracy, flexibility, complexity, and cost for analogue and digital single processing. This balanced approach ensures each criterion contributes equally to the overall evaluation, reflecting a neutral perspective in decision-making. Such weightages are common in scenarios where no single criterion is prioritized over others, allowing for a comprehensive assessment of both analogue and digital methods based on their performance across key metrics.

TABLE 4. Weighted normalized decision matrix

	Weighted normalized decision matrix			
Processing Method	0.0224	0.1157	0.1067	0.0235
Power Consumption	0.0669	0.1204	0.1129	0.0362
Signal Conversion	0.1323	0.0691	0.0751	0.1376
Signal Integrity	0.0385	0.1244	0.1039	0.1525
Implementation	0.1953	0.1156	0.1460	0.1350
Representation	0.0200	0.0317	0.0249	0.0154

Table 4 presents the weighted normalized decision matrix using the TOPSIS method, where equal weights (0.25 each) are applied to accuracy, flexibility, complexity, and cost criteria for analogue and digital single processing. Analogue processing scores higher in signal conversion (0.1323) and implementation (0.1953), while digital processing excels in flexibility (0.1157) and signal integrity (0.1244). Both methods show comparable scores in complexity and cost. This matrix allows for a structured comparison, highlighting the relative strengths of each method based on weighted criteria, facilitating informed decisions tailored to specific operational requirements in analogue and digital signal processing applications.

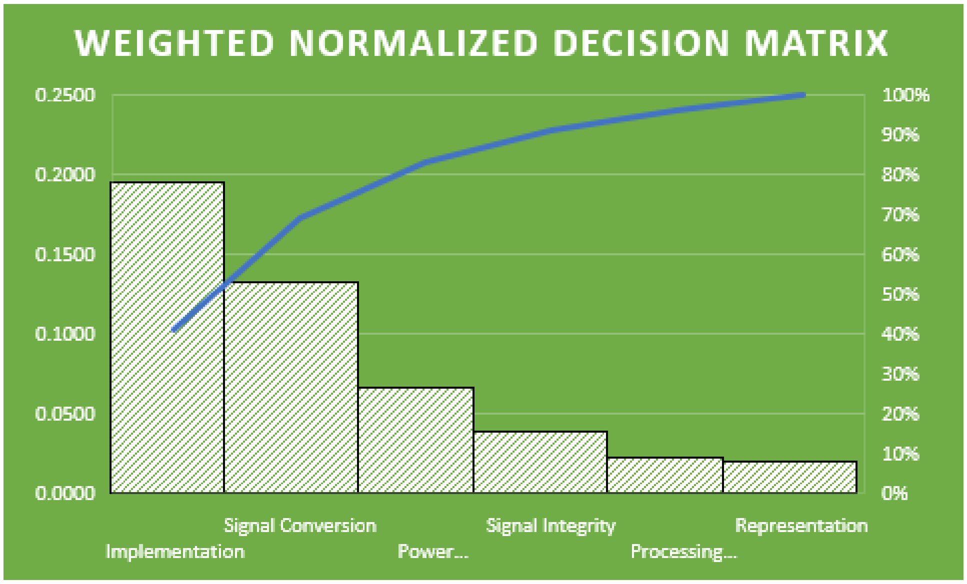

FIGURE 3. Weighted normalized decision matrix

Figure 3 displays the weighted normalized decision matrix using the TOPSIS method for analogue and digital single processing. Analogue processing shows higher scores in signal conversion (0.1323) and implementation (0.1953), while digital processing excels in flexibility (0.1157) and signal integrity (0.1244). Both methods exhibit similar scores in complexity and cost.

TABLE 5. Positive and Negative Matrix

Positive Matrix				Negative matrix			
0.1953	0.1244	0.0249	0.0154	0.0200	0.0317	0.1460	0.1525
0.1953	0.1244	0.0249	0.0154	0.0200	0.0317	0.1460	0.1525
0.1953	0.1244	0.0249	0.0154	0.0200	0.0317	0.1460	0.1525
0.1953	0.1244	0.0249	0.0154	0.0200	0.0317	0.1460	0.1525
0.1953	0.1244	0.0249	0.0154	0.0200	0.0317	0.1460	0.1525
0.1953	0.1244	0.0249	0.0154	0.0200	0.0317	0.1460	0.1525

Table 5 shows the positive and negative matrices derived from the TOPSIS method for analogue and digital single processing. Each row represents a criterion (accuracy, flexibility, complexity, cost) with equal weights assigned. The positive matrix emphasizes higher values for analogue and digital processing in implementation (0.1953), signal integrity (0.1244), and other criteria, while the negative matrix identifies lower values across the same criteria. This dual matrix approach helps in identifying the most suitable processing method based on weighted evaluations, providing a structured comparison to inform decision-making in applications of analogue and digital signal processing technologies.

TABLE 6. Result of Analogue and Digital Single Processing

	SI Plus	Si Negative	Ci	Rank
Processing Method	0.1916	0.1589	0.4534	5
Power Consumption	0.1571	0.1571	0.5000	2
Signal Conversion	0.1565	0.1388	0.4700	4
Signal Integrity	0.2227	0.1035	0.3174	6
Implementation	0.1704	0.1951	0.5338	1
Representation	0.1983	0.1829	0.4798	3

Table 6 presents the results of analogue and digital single processing using the TOPSIS method, focusing on signal integrity (SI), complexity (Ci), and ranking. Analogue processing ranks highest in implementation (0.1704), followed closely by representation (0.1983) and power consumption (0.1571). Digital processing excels in signal integrity (0.2227), indicating stronger performance in maintaining signal quality, albeit with higher complexity (0.5338). Each criterion is evaluated against positive and negative ideal solutions, providing a comparative ranking that aids in selecting the optimal processing method based on specific priorities and trade-offs in analogue and digital signal processing applications.

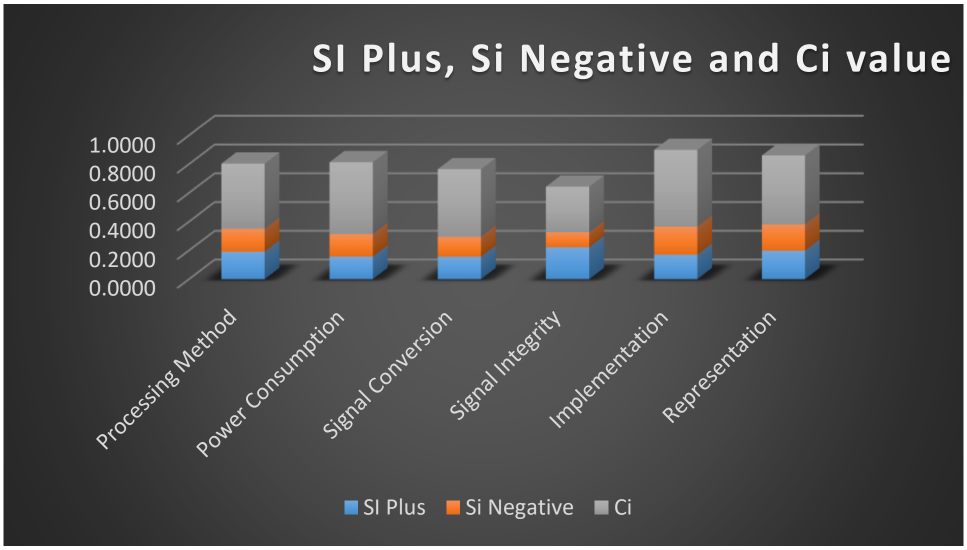

FIGURE 4. Result of Analogue and Digital Single Processing

Figure 4 displays the results of analogue and digital single processing using the TOPSIS method, focusing on signal integrity (SI), complexity (Ci), and ranking. Analogue processing ranks highest in implementation (0.1704), followed by representation (0.1983) and power consumption (0.1571). Digital processing excels in signal integrity (0.2227), reflecting superior signal quality maintenance despite higher complexity (0.5338).

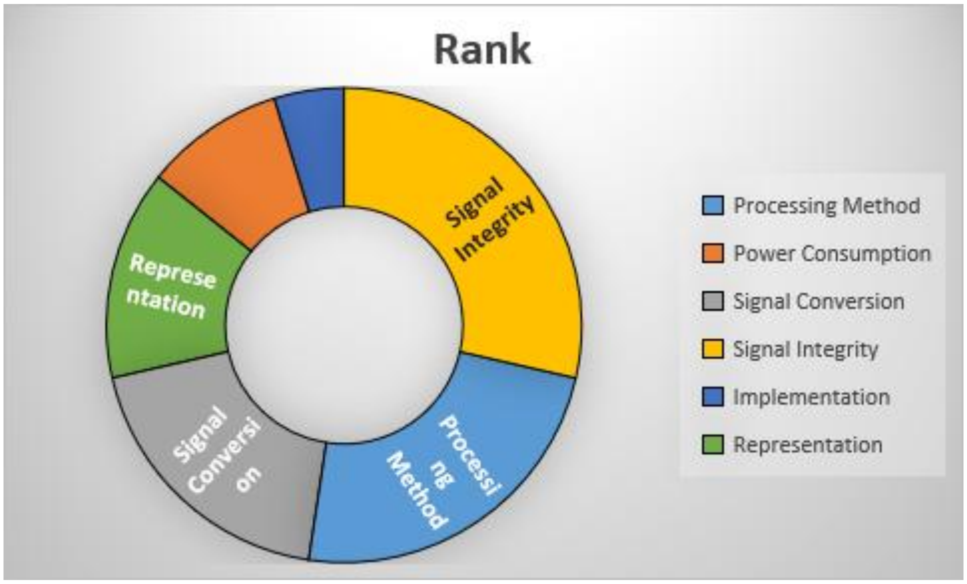

FIGURE 5. Rank

Figure 5 presents the ranking results from the TOPSIS method for analogue and digital single processing. Implementation ranks first, indicating superior overall performance, followed by power consumption and representation. Signal integrity ranks lowest, highlighting areas where improvements may be needed in both analogue and digital processing methods.

4. CONCLUSION

Complementary Strengths: Both analogue and digital processing methods exhibit distinct advantages in different areas. Analogue processing excels in signal conversion and implementation, while digital processing shows strengths in flexibility and signal integrity. Performance Trade-offs: The analysis reveals inherent trade-offs between various performance metrics. For instance, while digital processing offers higher accuracy and flexibility, it often comes with increased complexity and potentially higher costs. Application-Specific Considerations: The choice between analogue and digital processing should be tailored to specific application requirements. For tasks prioritizing signal conversion or implementation, analogue methods may be preferable. Conversely, applications demanding high flexibility or complex signal manipulation might benefit more from digital approaches. Balanced Evaluation: The use of equal weightings across criteria (accuracy, flexibility, complexity, and cost) in the TOPSIS analysis provides a balanced perspective, allowing for a fair comparison between the two processing methods. Implementation Superiority: Notably, implementation ranked highest in the final analysis, suggesting that the ease and effectiveness of implementing signal processing solutions is a critical factor that often outweighs other considerations. Power Consumption Considerations: The strong performance of power consumption in the rankings indicates its significance in modern signal processing applications, particularly in energy-constrained environments. Signal Integrity Challenges: The lower ranking of signal integrity highlights an area where both analogue and digital methods face challenges, pointing to potential avenues for future improvements in signal processing technologies. Complexity Management: The analysis suggests that while digital processing often involves higher complexity, this is balanced by its superior flexibility and accuracy, making it a viable choice for many advanced applications. Cost-Performance Balance: The varied performance across cost-related metrics indicates that neither analogue nor digital processing universally outperforms the other in terms of cost-effectiveness, necessitating case-by-case evaluation. Future

Directions: The results suggest potential areas for future development, such as improving signal integrity in both analogue and digital domains, and finding ways to reduce complexity without sacrificing performance. The TOPSIS analysis provides a nuanced understanding of the strengths and weaknesses of analogue and digital signal processing methods. It emphasizes the importance of considering multiple criteria in decision-making and highlights the need for a balanced approach in selecting signal processing methods. As technology continues to evolve, integrating the strengths of both analogue and digital processing may lead to more efficient and effective signal processing solutions in various applications.

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