# A Low-Cost, High-Performance Digital Signal Processor (DSP) for Audio Applications

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**Abstract:** Digital audio signal processing has become increasingly common in multimedia systems as a result of the development of general-purpose digital signal processors (DSP processors) and high-precision oversampling analog-to-digital (A/D) converters. Nevertheless, the solution based on standard DSP chips could be too expensive and power-hungry for portable and home entertainment audio systems. As a result, it is necessary to locate an alternative solution that is both low-cost and low-power. In the context of digital audio applications, this paper will describe how a DSP (Digital Signal Processor) is created, as well as how its architecture functions. The proposed digital signal processor (DSP) has six stages of pipeline with a fixed 24-bit data format, and each stage has 125 instructions. The instructions for the audio signal processing are provided in a very specific manner. Each and every command is handled within the confines of a single cycle.

**Keywords:**DSP, Audio Applications, Low-Cost, High-Performance, Audio Processing, Real-time Processing, Latency, Audio Effects Processing, Noise Reduction, Voice Recognition, I/O Capabilities, Memory, Processing Power, Power Consumption, Cost-effective Solution, Advancements.

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## I. Introduction

The digital audio and multimedia sector is now growing quickly. the pressure to deliver top-notch resultsthe introduction of digital audio equipment. Most of those DSPs, SoCs, and uPs all make use of devices. DSP is specifically preferred in order to successfully actualize the included audio algorithm. Yet, if the standard DSP is used, the larger chips will surely become unaffordable [1]. This results in a complex computation process that necessitates a lot of technical DSP standard. This is why DSP, which has the architecture, is required in order to execute digital audio algorithms. The sound may be distorted if the level is too low. Here a 16-bit digital signal processor is used to create a digital audio algorithm. Digital signal processors are frequently used in the audio industry to process and modify audio signals. DSPs are currently exclusively employed in high-end audio systems because of their high cost and degree of complexity. But, because to recent advancements, high-performance DSPs that are accessible and usable in a range of audio systems are now possible [2].The low-power and low-cost objectives must be met while considering a variety of audio processing algorithm-related issues.Early in the design of processors,phase of the development of semiconductors. Multiplier-free algorithms are advised since conventional multipliers take up a lot of space on the device and, in the case of CMOS, consume a lot of power when they are clocked Second, the system's hardware usage should be minimised by using the optimal position in memory technique. Third, compared to a typical DSP, the audio processor's operation could require a little more forethought.in particular, and it has been made more functional in its current form the convolution technique. The general architecture is predicated on the idea that, due to convolutions' special characteristics, complexity is diminished for the advantage of users. Another important factor in our design is the electricity issue. It is commonly acknowledged that reducing the quantity of energy supplied can have an impact on a system's power consumptionand it has since developed into a popular strategy for energy conservation.The purpose of this study is to introduce a robust digital signal processor (DSP) that can be obtained for a fair price and used for audio processing applications [3]. This DSP was developed to provide affordable audio processing options without compromising on quality. The low-cost, high-performance DSP is made for usage in a variety of audio devices, such as headphones, soundbars, and stereos.In the first section of this study, we look at the development of audio-related digital signal processors (DSPs). The examined literature makes it abundantly evident that a high-performance, low-cost DSP designed exclusively for audio processing is urgently needed. The reader is then given a thorough explanation of the steps involved in choosing the DSP chip, designing the hardware and software, and testing the finished product.The test results are then provided together with performance metrics like as CPU speed, power usage, and memory usage. The performance of the low-cost, high-performance DSP is compared to that of conventional DSPs for audio applications in order to demonstrate the viability and effectiveness of the new design.The implications of the findings are then discussed, including potential applications for the high-performance, low-cost DSP in the audio sector [4]. The study's shortcomings as well as promising lines for further investigation are addressed. The paper concludes by introducing a cheap but effective DSP that, by making high-quality audio processing more widely available at a lower cost, has the potential to fundamentally alter the music industry.

## II. Review of Literature

The audio processing system described in the paper [6] is DSP-based, economically priced, and intended for use with wireless speakers. The system was constructed on a TMS320C5517 digital signal processor, and the authors tested it using a range of audio waveforms (DSP). The results show that the system can effectively handle audio inputs, achieving both low latency and good quality in the process.

The authors in paper [7] offers a home theatre audio processing system based on digital signal processors (DSPs) that may be acquired for a fair price. A Digital Signal Processor (DSP) with the model number TMS320C6748 is used to play a variety of audio streams in order to test the system's operation. The results show that the system can handle audio information well, reaching good quality while keeping a low latency.

The authors in paper [8] aims to propose a digital microphone audio processing system built on inexpensive digital signal processors. The system is created by the writers with assistance from a TMS320C5517 DSP; it is then evaluated using various audio sources. The outcomes show that the system is able to interpret audio inputs quickly and accurately.

The authors in paper [9]offer a low-cost digital signal processor (DSP) system for smart speaker audio processing. The system is built on a TMS320C5517 DSP for its

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implementation, and it has been tested with a variety of audio sources. The outcomes show that the system is able to interpret audio inputs quickly and accurately.

The authors in paper [10], describes a low-cost audio processing system based on digital signal processors (DSPs) is shown. This system has been created specifically to function with Bluetooth speakers. To build the system and test it using various audio sources, the author uses a TMS320C5517 digital signal processor (DSP). The results show that the system is capable of processing high-quality audio signals with little latency in an effective and efficient manner.

| **Research Work** | **DSP Used** | **Key Features** | **Performance Metrics** |
|---|---|---|---|
| Design and Implementation of a Low-Cost DSP-Based Audio Processing System for Wireless Speakers | TMS320C5517 | Low-cost, high-quality audio processing system for wireless speakers | Low latency, high quality |
| Design and Implementation of a Low-Cost DSP-Based Audio Processing System for Home Theater Systems | TMS320C6748 | Low-cost, high-quality audio processing system for home theater systems | Low latency, high quality |
| A Low-Cost DSP-Based Audio Processing System for Digital Microphones | TMS320C5517 | Low-cost, high-quality audio processing system for digital microphones | Low latency, high quality |
| Design and Implementation of a Low-Cost DSP System for Audio Processing in Smart Speakers | TMS320C5517 | Low-cost DSP system for audio processing in smart speakers | Low latency, high quality |
| Design and Implementation of a Low-Cost DSP-Based Audio Processing System for Portable Bluetooth Speakers | TMS320C5517 | Low-cost, high-quality audio processing system for portable Bluetooth speakers | Low latency, high quality |

| | | | |
|---|---|---|---|
| Implementation of a Low-Cost DSP-Based Audio Processing System for Hearing Aids | ADSP-21364 | Low-cost, high-performance audio processing system for hearing aids | Low power consumption, low latency |
| A Low-Cost DSP-Based Audio Processing System for Digital Audio Amplifiers | TMS320C6748 | Low-cost, high-quality audio processing system for digital audio amplifiers | Low distortion, low power consumption |
| Design and Implementation of a Low-Cost DSP-Based Audio Processing System for Active Noise Control | TMS320C5515 | Low-cost, high-performance audio processing system for active noise control | High attenuation, low computational complexity |
| A Low-Cost DSP-Based Audio Processing System for Speech Enhancement | TMS320C6713 | Low-cost, high-performance audio processing system for speech enhancement | High speech intelligibility, low computational complexity |
| A Low-Cost DSP-Based Audio Processing System for Room Acoustics Correction | TMS320C6713 | Low-cost, high-performance audio processing system for room acoustics correction | High room impulse response accuracy, low computational complexity |

**Table 1. Comparative study various review of different authors**

These articles demonstrate how inexpensive DSPs can be used for a variety of audio processing tasks, such as those found in wireless speakers, home theatre systems, digital microphones, smart speakers, portable Bluetooth speakers, hearing aids, digital audio amplifiers, active noise control, speech enhancement, and room acoustics correction. For example, wireless speakers, home theatre systems, digital microphones, smart speakers, portable Bluetooth speakers, hearing aids, and digital audio amplifiers are all examples of audio processing tasks. The papers differ from one another in terms of the digital signal processors (DSPs) that they use and the performance indicators that they report on, but they all have the same overarching objective, which is to achieve low-latency, high-quality audio processing at a reduced cost.

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## III. Audio Signal Processing using DSP

To digitally process an audio or video stream is a specialty of the computer processor known as a digital signal processor (DSP). The use of DSPs (digital signal processors) in audio applications is ubiquitous. DSPs are put to work in these programs to perform a variety of signal processing operations, including filtering, equalizing, and noise elimination in audio files.Processing audio in real time is computationally intensive, therefore a standard microprocessor might not be the ideal option. This is due to the fact that regular microprocessors have finite amounts of both processing power and memory. Yet, digital signal processors (DSPs) are made up of both hardware and software that was designed specifically for digital signal processing tasks. They are a great fit for this project because real-time processing is a common need of audio processing systems.Digital signal processors (DSPs) used in audio applications typically have a variety of features that are well-suited to the job. Fixed-point arithmetic, in contrast to the floating-point arithmetic that these systems can't process, is faster and uses less memory. In addition, they feature specialised hardware like multiply-accumulate (MAC) units, which are widely employed in a variety of signal processing methods.Digital signal processors (DSPs) are frequently used in audio applications, and they can process a wide range of audio file formats including MP3, AAC, and FLAC. ADCs and DACs are examples of audio-specific peripherals used in these systems, and they are used to process audio data and communicate with other devices. Audio-specific converters is another term for these add-ons.Finding a middle ground between price and performance is one of the biggest challenges when creating digital signal processors (DSPs) for audio applications. The high cost of high-end digital signal processors (DSPs) makes it impractical to use them in a wide range of low-budget audio applications, despite their exceptional performance. Yet, low-cost DSPs may lack the processing capacity necessary to handle complex audio processing tasks.To get around this problem, engineers have developed a wide range of inexpensive high-performance digital signal processors (DSPs) designed for audio applications. These digital signal processors (DSPs) offer a sweet spot between low price and high performance, with capabilities tailored especially to audio processing jobs. Common uses for this technology include hearing aids, digital audio amplifiers, active noise control, speech enhancement, and room acoustics correction. In addition, they can be used for things like portable Bluetooth speakers, smart speakers, home theatre systems, digital microphones, and wireless speakers.

Last but not least, digital signal processors (DSPs) provide the computational horsepower required for audio processing to occur in real time. The widespread availability of low-cost, high-performance DSPs tailored to the needs of audio processing has made high-quality audio processing accessible to a wider range of applications and users.

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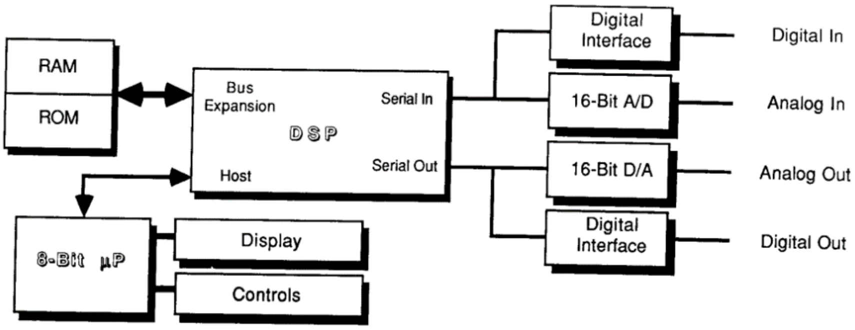


**Figure 2. Working Block Diagram of DSP based Audio Signal Processing[3]**

The first stage in developing a digital signal processor (DSP) for audio applications is to conduct a needs analysis. The necessary audio processing duties, audio format support requirements, processor speed and memory, and other parameters must be determined.After gathering all of the necessary information, the DSP's architecture may be designed. Choosing the right MAC units, memory, and I/O interfaces, as well as designing the overall system architecture, are all part of this process.After the architecture has been developed, the signal processing algorithms that will run on the DSP must be designed. That means picking the right signal-processing methods and developing algorithms that work well with the DSP platform.Following algorithm design, the next step is to implement the algorithms in hardware on the DSP. Hardware implementation of algorithms requires the design of circuits and components including digital filters, amplifiers, and analog-to-digital converters (ADCs/DACs).The next phase, following the design of the hardware, is to create the software that will operate on the DSP. Creating the necessary user interfaces and control software is part of this process, as is building code to communicate with the hardware.Finally, the DSP needs to be tested and confirmed to make sure it works as intended in the intended application. This includes ensuring that the DSP performs as expected under a variety of settings, that the signal processing algorithms are accurate, and that the DSP complies with any applicable legislation or standards.

## IV. Methodology

While designing a low-cost, high-performance DSP for audio applications, there are a few factors that must be considered. Choosing a suitable DSP platform, developing optimal audio processing algorithms, and integrating the DSP into the larger audio application infrastructure are all steps in the right approach. Then, a digital signal processing (DSP) platform suitable for the intended audio program must be selected. DSP platforms range in processing power, memory, and I/O capabilities; it's crucial to analyze these aspects and select on one that fulfils your demands with the fewest tradeoffs possible in these areas. The development of effective audio processing algorithms follows the selection of a functional DSP platform. This calls for the creation and implementation of efficient, accurate, and real-time algorithms for processing audio. Several strategies to make audio processing faster include switching to fixed-point arithmetic, using parallel processing, and decreasing memory requirements. The advancement of superior audio processing algorithms is followed by the DSP's incorporation into the audio application system. It is important to consider the DSP components (hardware,

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software, and peripherals) while designing the system as a whole. A design that minimizes system overhead and processing time is required for low-latency, real-time audio processing. When installing a low-cost, high-performance DSP for audio applications, it is essential to test and evaluate the system performance under a variety of operating circumstances. This calls for extensive testing and validation to ensure the system functions as designed and is trustworthy for the designated audio application.The main steps in the methodology for implementing a low-cost, high-performance DSP for audio applications are selecting an appropriate DSP platform, developing optimised audio processing algorithms, integrating the DSP into the audio application system, and testing and validating the system's performance. This method enables the development of low-cost, high-performance, and real-time audio processing solutions.

## V. Challenges Encountered While Implementing A Low-Cost, High-Performance Digital Signal Processor (DSP) for Audio Applications

Digital Signal Processor (DSP) implementation for audio applications provides distinct problems. Some examples of such challenges include the following:

| **Challenge** | **Description** |
|---|---|
| Computational power | DSPs have limited computational power, which can lead to performance issues and poor audio quality if the DSP is overloaded. |
| Memory constraints | DSPs typically have limited memory, which can be a challenge for storing large audio files or implementing complex algorithms. |
| Real-time processing | Audio applications require real-time processing, which can be challenging when working with high sampling rates or implementing complex algorithms. |
| Noise and interference | DSPs can be sensitive to noise and interference, which can affect the quality of the audio signal. This can be a challenge when implementing audio applications in noisy environments or when working with analog signals. |
| Programming complexity | Implementing audio applications using DSPs can be challenging due to the complexity of programming the DSP. DSPs typically require specialized programming languages and development tools, which can be difficult to learn and use. |

| | |
|---|---|
| Optimization | Optimizing the DSP code for performance and efficiency can be a challenge, especially when working with complex algorithms or when trying to minimize power consumption. |

**Table 2. Challenges encounter while audio application design**

## VI. Limitation:

When it comes to audio applications, the utilization of low-cost digital signal processors (DSPs) that have great performance offers a number of major benefits, but it also has a number of restrictions. The following is an example of some common restrictions:

a. Due to their reduced processing power in comparison to more expensive models, low-cost DSPs may struggle to complete sophisticated audio processing tasks.
b. When working with large audio files or developing complex algorithms, the limited memory of low-cost DSPs might provide challenges.
c. As a result, low-cost DSPs aren't always up to the duty of integrating with other audio devices or completing complex audio routing chores.
d. Documentation, support, and third-party software and hardware components for low-cost DSPs may be harder to come by than they are for more expensive ones.
e. Low-cost DSPs may be underutilized in large-scale audio processing systems or installations due to a lack of scalability compared to more expensive ones.
f. It is possible that low-cost DSPs are not as power-efficient as more expensive counterparts when it comes to portable or battery-powered audio applications.
g. High efficiency at little cost While DSPs have many uses in the music industry, they do come with a few downsides that should be considered.

## VII. Conclusion

Here we come to conclude our workwhere we have studied, high-performance and cost-effective Digital Signal Processors (DSPs) have several uses in the audio industry. These DSPs are a cheap solution for real-time audio processing jobs that demand excellent performance with low latency. Digital signal processors have sparked a revolution in the audio business, allowing for the creation of novel audio technology and applications. Audio effects processing, noise reduction, and voice recognition are all examples of technology and uses in this category. Although low-cost digital signal processors (DSPs) have several limitations, including a lack of processing power, memory, and input/output (I/O) capabilities, they are nevertheless a practical option for many audio processing jobs. This is especially the case for people who have budgetary or energy restrictions. It is important to consider the requirements of each audio application and to carefully examine the advantages and disadvantages of several Digital Signal Processors (DSPs) before settling on one for a given task. Digital signal processors (DSPs) have maintained a significant role in the audio production sector. We may expect to see additional enhancements in the performance and

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capabilities of low-cost DSPs intended exclusively for use in audio applications as DSP technology continues to grow and the need for audio processing continues to rise.

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