AmpLink: Smart Wireless Guitar Amplifier with Mobile App and Built-in Speaker

A Project Study

Presented to the

Faculty of College of Engineering

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Chapter 1: Introduction

1.1 Background of Study

Music technology has engaged a remarkable transformation over the past few decades, reshaping how musicians interact with sound. Among the most significant changes is the shift from analog to digital solutions, particularly in how guitarists amplify, process, and manipulate their tone. Guitar amplifiers once large, heavy, and expensive pieces of hardware have now been replicated through software using advanced signal processing techniques. As a result, musicians are no longer restricted to carrying physical gear or investing in costly equipment to achieve a professional sound. Instead, software-based alternatives such as guitar amplifier applications are offering new possibilities in terms of convenience, creativity, and control. At their core, guitar amplifier apps digitally emulate the sound-shaping functions of physical amplifiers. They allow guitarists to connect their instruments to smartphones, tablets, or computers and access a wide array of amp models, speaker cabinet simulations, tone controls, and built-in effects. These apps are not just digital replicas they often go beyond the capabilities of physical amps by enabling deep customization, user presets, and integration with other music production tools. In practical terms, this means that both beginner and experienced players can experiment with tone and effects without needing a full physical rig.

Initially originating as analog tube-based devices, guitar amplifier technology has evolved to include extremely complex digital solutions. In opposite of early amplifiers that mainly projected sound and shaped tone, contemporary systems incorporate digital signal processing (DSP), deep learning to simulate, improve, and expand musical possibilities (Schmitz et al., 2020; Martínez Ramírez et al., 2022).

Recent studies demonstrate the pioneered the application of deep learning to real-time guitar amplifier emulation, how neural networks effectively capture the nonlinear response of tube amplifiers in real time (Schmitz et al., 2020), while newer approaches such as hypernetworks enable an amplifier simulator modeling without retraining (Martinek & Černocký, 2024, October). Other frameworks, like the DDSP Guitar Amp, embed differentiable DSP components into deep learning models to improve interpretability (Heinonen & Välimäki, 2024). These innovations reflect the increasing demand for both tonal authenticity and technological flexibility.

From a technological standpoint, the development of guitar amplifier apps is the product of several converging innovations. Improvements in mobile computing power, the efficiency of real-time digital signal processing (DSP), and the growing accessibility of audio plugin frameworks have made it possible to run high-quality audio simulations on handheld devices. Where once only desktop workstations could handle detailed amp modeling, modern smartphones and tablets are now capable of producing studio-grade tones with minimal latency. This has opened the door for guitar apps to become a viable alternative not just for practice, but for live performance and professional recording as well.

Efficiency has also been a focus, with adversarial learning reducing dataset requirements (Schmitz et al., 2023) and pruning strategies balancing performance with computational demands (Perello Nieto et al., 2023). Accessibility has expanded through browser-based amplifier simulations, making real-time modeling possible without specialized hardware (Orlarey et al., 2023).

Musically, this shift represents a significant opportunity for creative exploration. Traditional analog gear often limits musicians to a few core tones due to cost and physical space. In contrast, guitar amp apps usually come with dozens of amp and effect models built-in, allowing users to simulate classic tube amps, high-gain stacks, boutique pedals, and experimental effects chains all from a single device.
This variety supports creativity and allows guitarists to explore and refine their personal sound without needing access to high-end equipment. It also encourages experimentation, since changing gear or settings in an app takes seconds, whereas doing so in a physical setup could require rewiring and recalibration. User experience plays a major role in the appeal of guitar amplifier apps. Unlike traditional gear that may require technical knowledge or setup time, most modern apps are designed with user-friendly interfaces. Touchscreen controls, visual representations of amps and pedals, and preset management make it easier for musicians to navigate complex tone-shaping options. Many apps also support direct recording, looping, and integration with backing tracks, turning a smartphone or laptop into a complete practice or performance rig. For traveling musicians, this means significantly reduced gear load without sacrificing tonal quality.

From an educational perspective, guitar amplifier apps are also becoming essential tools. They support music learners by providing access to professional tones without needing expensive gear, which lowers the barrier to entry for aspiring guitarists. Many amp apps also include learning features such as built-in tuners, metronomes, scale libraries, or integration with guitar teaching platforms. Instructors can use these tools to demonstrate effects, tone shaping, or genre-specific settings in real time, offering a more interactive and modern approach to music education. The rise of these apps is not just a passing trend it reflects broader shifts in the music industry. Digital modeling amplifiers are now widely accepted on professional stages and in studios. Major brands have embraced digital innovation, and software-based gear is now part of the standard toolkit for many modern guitarists. The growth of mobile music production, streaming content creation, and virtual learning platforms all point to a future in which software plays a central role in musicians' daily practice.

Beyond technology, adoption trends reveal a cultural shift. Digital guitar amps are increasingly used in live music settings, with even tone purists gradually embracing modeling technology (Vincent, 2025). Portable and app-enabled devices, such as the Hotone Pulze Mini Bluetooth Amp, demonstrate how integration with learning tools and interactivity are broadening amplifiers to include practice and pedagogy (Leonard, 2025; Ubisoft's Rocksmith, 2022).

Given this, combining smartphone apps with guitar amplifiers seems like a good course of action. By providing artists with real-time control, portability, and interactive features that complement contemporary technological and cultural trends, mobile platforms can enhance the possibilities of digital amplifiers. In essence, this study responds to a growing demand in music technology to make professional-quality tone and flexible sound design accessible to everyone to anywhere, anytime, and on any device.

1.2 Statement of the Problem

While there are several commercial guitar amplifier apps in the market, many are either too expensive, resource-intensive, or lack customization and user-friendliness. For beginner musicians or those with limited access to high-end equipment.

1. What are the key features that users expect from a modern guitar app?

2. How does the amplifier speaker manage processing when connected to electric guitar application?

3. What possible innovations can shape the future of guitar amplifier technology through mobile app integration?

4. To evaluate the acceptability in terms of.6

   - Adaptability
   - Functionality
   - Friendliness

1.3 Objectives of the Study General Objective:

1.3.1 General Objective

To develop a functional and user-friendly Guitar Amplifier App that emulates real-world amplifier and effects processing. Specific Objectives: To design an intuitive user interface suitable for musicians. To implement real-time digital signal processing algorithms for guitar tone shaping. To integrate multiple amp models and effects. To evaluate the app's performance, sound quality, and user experience through testing and feedback.

1.3.2 Specific Objective

1. To design an intuitive and musician-friendly interface that makes navigation and customization simple and efficient.

   To assess the efficiency of the amplifier speaker when connected to an electric guitar application.

2. To ensure the application delivers high-quality audio output, optimized performance, and stability suitable for practice, small gig, etc.

3. Evaluate the acceptability of a novel guitar amplifier system in terms of adaptability, functionality, and friendliness, using a standardized usability questionnaire administered to a sample of guitarists.

1.4 Significance of Study

The development of a Guitar Amplifier Application is both relevant and timely in today's music industry, where digital solutions are increasingly replacing bulky and expensive hardware. Traditional amplifiers and effects pedals, while effective in producing quality tones, can be financially burdensome and impractical to carry around. With the rise of home recording, online content creation, and virtual performances, there is a growing need for affordable, portable, and user-friendly alternatives.

- **Aspiring Musicians** will gain an affordable and portable alternative to traditional amplifiers and pedals.
- **Music Educators** can use the app as a convenient teaching tool, demonstrating amplifier behavior and sound shaping techniques in classrooms.
- **Researchers** will benefit from its contribution to the growing body of literature on digital audio processing and virtual amp modeling.

1.5 Scope and Delimitation

1.5.1 Scope

- Concentrates on how mobile apps are integrated with guitar amplifier systems.
- Incorporating effects and digital amplifier simulations to imitate key aspects of traditional guitar amplifiers.
- Involving Wireless Connection to provide a smooth connection between the mobile application and the electric guitar (via an interface).

- Application for personal practice, small performances, and educational purposes.

1.5.2 Delimitations

- Does not aim to replace professional amplifiers for large events.
- User evaluation is limited and may not represent all electric guitarists.
- Limited testing across Android devices only, excluding iOS due to platform constraints.

1.6 Theoretical Framework

The development of a mobile platform application for a guitar amplifier is guided by several interconnected theories that, when combined, form the backbone of this study. At its heart, the project begins with the idea of how sound from an electric guitar is transformed. This is where Digital Signal Processing (DSP) comes in. Imagine a guitarist striking a chord: the vibrations from the strings are captured as analog signals, which the amplifier must shape into the rich tones musicians expect. Through DSP, those signals are converted into digital data, carefully manipulated, and reconstructed to produce clear, accurate sound. Without DSP, the system would lack the precision needed to model tones, add effects, and adapt to different musical styles.

But the amplifier is no longer confined to being a simple box of electronics. In this study, it becomes part of a connected ecosystem. Here, Wireless Communication Theory plays its role. By integrating ESP32 technology with Bluetooth or Wi-Fi, the amplifier speaks directly to the mobile application. Instead of manually twisting knobs, guitarists can now adjust tone, gain, or effects on their phone even in real time while performing. This seamless connection between hardware and software reflects a growing trend in music technology, where control is untethered and flexibility is prioritized.

Finally, the principles of portable audio system design ground this study in the physical realities of the amplifier itself. A portable guitar amplifier must strike a balance between size, weight, and sound performance. Too large, and it loses mobility; too small, and it may fail to deliver the necessary sound projection. The design of the speaker enclosure, the efficiency of power usage, and the quality of sound output are all key considerations. These engineering principles ensure that the amplifier remains both practical and reliable, providing high-quality sound in a form that is easy to transport and use in different settings.

1.7 Conceptual Framework

The study's conceptual framework, depicting, the Input – Process – Output concept is presented below.

INPUT

Knowledge Requirements

-Programming

-Machine Learning

-Circuit and Electronics

-Android Studio

-Amplifier

Programming Language Used

-Flutter

Hardware

-ESP32

-3-way crossover amplifier

-Power Supply

-Speaker Unit and Box

-Audio input

- Bluetooth Jack

PROCESS

Hardware Development Planning

-Design and Prototype

-Construction of amplifier speaker

-Testing

-Implementation

System Analysis

-Requirement Analysis

-Requirement description and design specifications

Mobile App

-Requirement Design

-Programming

-Testing

-Evaluation

-Deployment

-Maintenance and Updates

OUTPUT

AmpLink: Smart Wireless Electric Guitar Amplifier with Mobile App and Built-in Speaker

Figure 1: INPUT – PROCESS - OUTPUT

CHAPTER 2: REVIEW OF RELATED LITERATURE AND STUDIES

2.1 Review of Related Literature

This section discusses the theoretical background of the study. The theories and concepts behind the research study are here.

Advances in Amplifier Emulation

The field of guitar amplification has undergone a profound transformation, shifting from analog circuits rooted in tube-based designs to sophisticated digital solutions powered by artificial intelligence and machine learning. While early amplifiers were primarily designed to project sound and shape tone, today's systems have evolved into versatile, intelligent tools capable of emulating, enhancing, and extending sonic possibilities. This evolution is not only a response to technological innovation but also to the needs of modern guitarists, who increasingly value portability, affordability, and flexibility alongside tonal authenticity.

The pioneered the application of deep learning to real-time guitar amplifier emulation, showing that neural networks can effectively capture the nonlinear response characteristics of tube amplifiers in live performance contexts (Schmitz et al., 2020). Building on this, (Martínez Ramírez et al., 2022) provided a comprehensive review of neural network-based emulation techniques, comparing traditional DSP methods with modern deep learning approaches, and identifying trade-offs between computational efficiency and accuracy.

Further advancements introduced specialized modeling strategies. (Martinek & Černocký, 2024, October) proposed an amp simulator amplifier modeling, allowing new amplifier tones to be replicated without retraining. While presented the DSP Guitar Amp, which integrated differentiable DSP components into deep learning frameworks to prioritize interpretability (Heinonen & Välimäki, 2024). Similarly, explored end-to-end controllable models, shifting the emphasis from tone replication to providing musicians with flexible control over amplifier characteristics (Martinek & Černocký, 2024, March).

Improving Efficiency in Deep Learning Models

The computational demands of deep learning models have also been a focus of research proposed adversarial learning methods for amplifier modeling, enabling training with unpaired data and reducing the burden of collecting large, paired datasets (Schmitz et al., 2023). Further advanced this direction by applying pruning strategies to deep neural networks for guitar distortion effects, striking a balance between model performance and efficiency. Simple Science AI extended this trajectory by introducing one-to-many modeling via tone embedding, creating versatile models capable of capturing multiple amplifier signatures within a unified framework (Perello Nieto et al., 2023).

The application of deep neural networks can replicate the complex sound of audio distortion circuits, like those in guitar amplifiers and pedals. A WaveNet-style feedforward network with a recurrent neural network. To optimize the WaveNet, they discovered that just three minutes of audio is sufficient for training. The models were tested in real-time to assess their processing demands. The results indicated that while some listeners could distinguish the model of the Blackstar amp from the original, the sound quality was still rated as excellent. For the Mesa Boogie amp, many couldn't tell the difference at all. They conclude that neural networks can effectively mimic nonlinear audio distortion in real-time, with some requiring minimal processing power on modern computers (Wright, A., et al 2020).

In addition to deep learning, alternative modeling approaches have been explored. demonstrated the feasibility of browser-based simulations of tube guitar amplifiers, making real-time modeling accessible without specialized hardware. These developments emphasize accessibility and portability, aligning with broader trends in music technology (Orlarey et al., 2023). While neural network models for guitar amplifier emulation are effective, they can be computationally expensive and difficult to analyze. This paper aims to address these issues with a new differentiable digital signal processing (DDSP)-based model, called "DDSP guitar amp," that models the four components of a guitar amp using specific DSP-inspired designs. With a set of time- and frequency-domain metrics (Yen-Tung Yeh, et al. 2024).

2.2 Review of Related Studies

Digital Amplification

DSP has been at the forefront of industry applications. Between 2020 and 2024, the company developed the Quad Cortex, a flagship neural modeling processor that integrates advanced profiling and deep learning. Recently, Neural DSP introduced the TINA robotic profiling system, further automating the capture of amplifier tones (Neural DSP, 2024). (Murray, 2025) reviewed the Neural DSP Nano Cortex, highlighting its compact design, versatile sound library, and user-driven customization features.

According to the article, a high-output impedance audio power amplifier can be used to evaluate a guitar cabinet's frequency response. In addition to lowering the sound pressure level of the guitar amplifier and cabinet set, the proposed solution is made for digital modeling systems of the electric guitar sound processing path. Additionally, the system's possible use in identifying the speaker set's impedance characteristics is emphasized (SZUBERT, Michał and SZYBIŃSKI, Krzysztof 2025). Kemper GmbH has also been a significant player since the introduction of the Kemper Profiler. Its 2023 update on “liquid profiling” refined amplifier capturing to improve realism and playability (Kemper GmbH, 2023). These developments illustrate the growing competition between profiling and deep learning-based systems.

This article explores how the electric guitar was invented and how it has been improved over time. It looks at the circumstances that led to its creation and connects the invention to ideas from social sciences and philosophy to explain where it came from and how it has changed as an instrument. The second part of the article compares different musical pieces written for enhanced electric guitars. This comparison helps to show how adding new features to the guitar has influenced its use. By studying these examples, the article suggests that recent improvements to the instrument have been driven by a desire for more electronic adaptability, better performance during playing, volume control, and built-in computer capabilities. Finally, the article talks about different parts of the instrument's enhancement process, focusing on how musical performance and the development of performance skills have played a role (Daniel Santos, Henrique Portovedo 2021).

Adoption and Cultural Shifts

The evolving dynamics of live music are significantly influenced by the growing presence of digital guitar amplifiers, as evidenced by recent studies highlighting a distinct movement among professional musicians away from conventional analog amplifiers and toward digital alternatives. This transition is largely driven by the inherent benefits of digital amplifiers, which provide greater versatility in sound customization, a more manageable form factor for touring musicians, and the ability to save and access a comprehensive range of personalized configurations. While analog amplifiers have historically been prized for their immediate, physical connection and distinctive harmonic qualities, advancements in digital modeling have enabled these technologies to convincingly replicate such attributes, albeit through different technological means. Research also indicates a measured acceptance of these modeling technologies among tone aficionados, a community renowned for their commitment to the preservation of classic amplifiers and effects. This acceptance is tempered by certain reservations, as many purists voice apprehensions regarding the potential for unwanted digital distortions, a diminished sense of dynamic interaction, and a disconnect from the tangible engagement associated with analog equipment (Vincent, 2025). Nevertheless, the report posits that the functional advantages of digital amplifiers, coupled with ongoing enhancements in the precision of digital modeling, are gradually mitigating resistance and cultivating a more accommodating perspective on guitar amplification within live performance environments and recently article reported significant growth in the global electric guitar amplifier market, driven by digital modeling, portability, and integration with production ecosystems. (Leonard, 2025) echoed this consumer shift in his review of the Hotone Pulze Mini Bluetooth Amp, a portable device tailored for home practice and mobility. Integrates amplifier modeling with interactive music learning, offering users real-time tone recognition and feedback in a subscription-based educational service. This highlights how amplifier technologies are not only used in performance and recording but also in pedagogy, broadening their societal relevance (Ubisoft's Rocksmith, 2022).

Chapter 3 Research Methodology

3.1 Research Design

This study employs a developmental research design that focuses on designing, prototyping, and testing the AmpLink: Smart Wireless Guitar Amplifier with Mobile App and Built-in Speaker. The research follows the Engineering Design Process (EDP) which includes problem identification, analysis, prototype development, evaluation, and refinement. The primary goal of this study is to integrate digital signal processing (DSP), wireless communication, mobile app control, and portable speaker design into a single amplifier prototype. This design is appropriate because the project aims to create a functional prototype that addresses the limitations of traditional guitar amplifiers, such as lack of portability, absence of mobile app integration, and limited wireless connectivity.

3.2 Software Process Model

The researchers adopted the Agile Software Process Model for the development of the AmpLink system. Agile was chosen because it emphasizes flexibility, adaptability, and incremental development, allowing the researchers to improve the system continuously based on user feedback and prototype testing. The Agile process in this study that includes the following phases

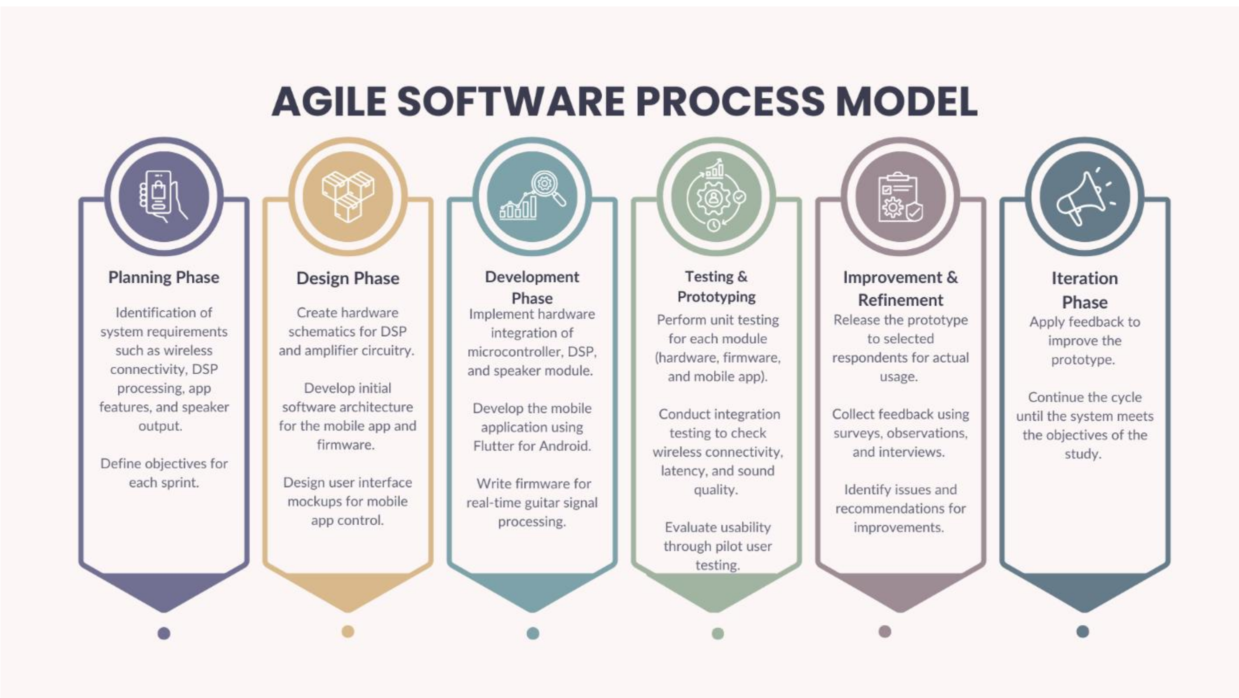

Figure 3.1 Agile Software Process Model

3.3 Sources of Data

Data is gathered through collected research and gathering information. The collected research is the primary source of the data; this study will be obtained directly from the respondents and through experimental testing. Surveys and questionnaires will be conducted among guitarists, music students, and audio enthusiasts to gather feedback on their experiences in using mobile and web-based amplifier applications. The survey will focus on key aspects including usability, latency, sound quality, portability, and overall satisfaction. In addition, semi-structured interviews with local musicians and music educators will be carried out to provide deeper insights into the acceptance, advantages, and limitations of mobile or web-based amplifiers compared to traditional hardware amplifiers. Furthermore, experimental testing of selected applications will be performed to measure technical performance. This includes hands-on trials to evaluate latency, tonal accuracy, and ease of integration in different contexts such as home practice, classroom learning, and live performance. Data will also be collected using frequency response analysis and latency measurement tools to ensure objective evaluation.

Materials and Software Used

3.3.1 lectric Guitar

Figure 3. Electric Guitar
(https://www.yamaha.com/en/musical_instrument_guide/electric_guitar/mechanism/)

An electric guitar is a stringed musical instrument that uses electromagnetic pickups to convert the vibration of its metal strings into electrical signals.

3.3.2 3-way Speaker

Figure 3.2 3-way Speaker

A 3-way speaker separates the audio signal into three frequency bands low, mid, and high and sends each band to a dedicated driver for reproduction.

3.3.3 3-way Crossover Amplifier

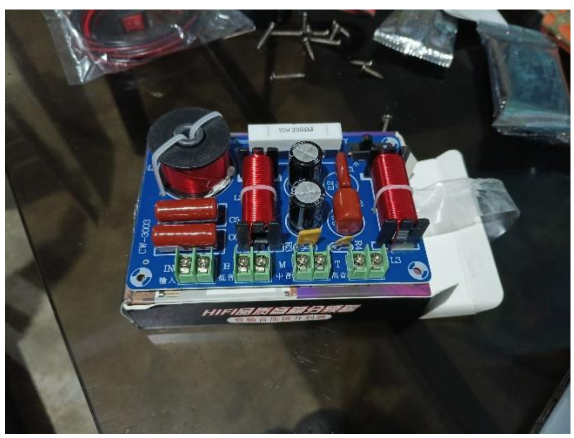

Figure 3.3 3-way Crossover Amplifier

An audio system configuration where a 3-way crossover works with multiple amplifiers to direct specific frequency bands to their corresponding speakers (tweeters, midrange, and woofers) that will connect in 3-way speaker.

3.3.4 ESP32 with expansion board

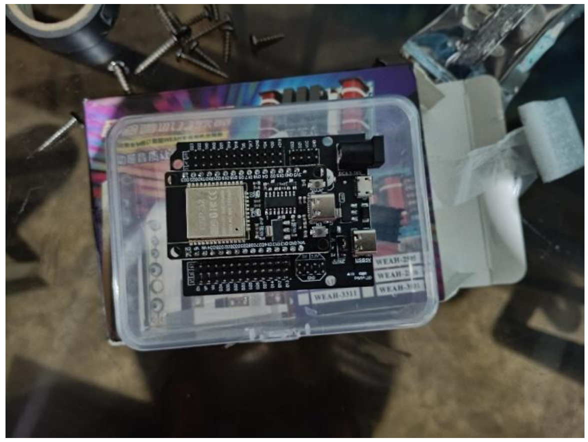

Figure 3.4 ESP32 with expansion board

ESP32 with expansion board will be the brain of the application to the amplifier

3.3.5 Power Supply

Figure 3.5 Power Supply

The power supply will be source of power on ESP32.

3.3.6 Bluetooth Jack

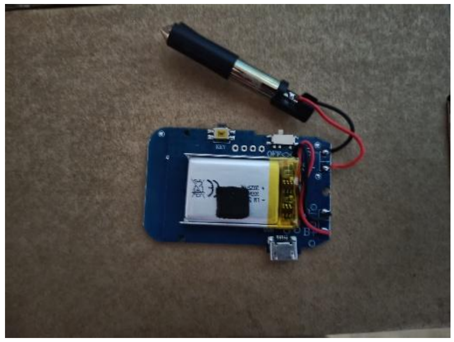

Figure 3.6 Bluetooth Jack

This Bluetooth jack model is for wireless connection in electric guitar to Esp32.

3.3.7 Application

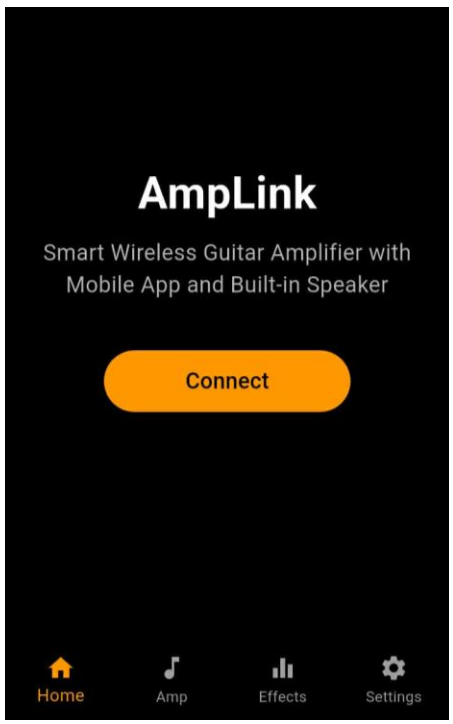

Figure 3.7Application

To able control the guitar amplifier effects.

3.4 System Block Diagram

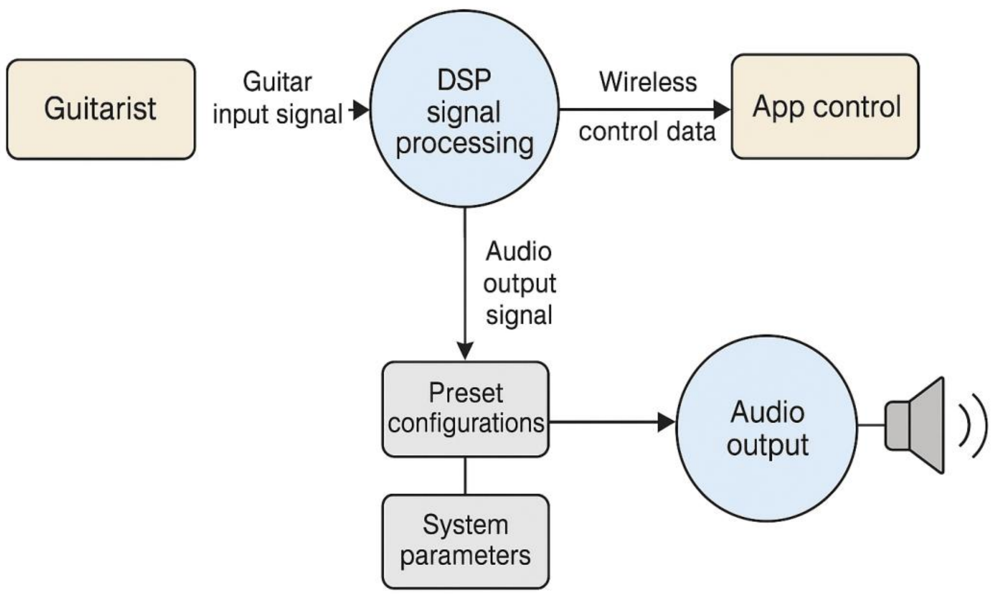

Figure 3.8 Data Flow Diagram

3.5 FLOWCHART

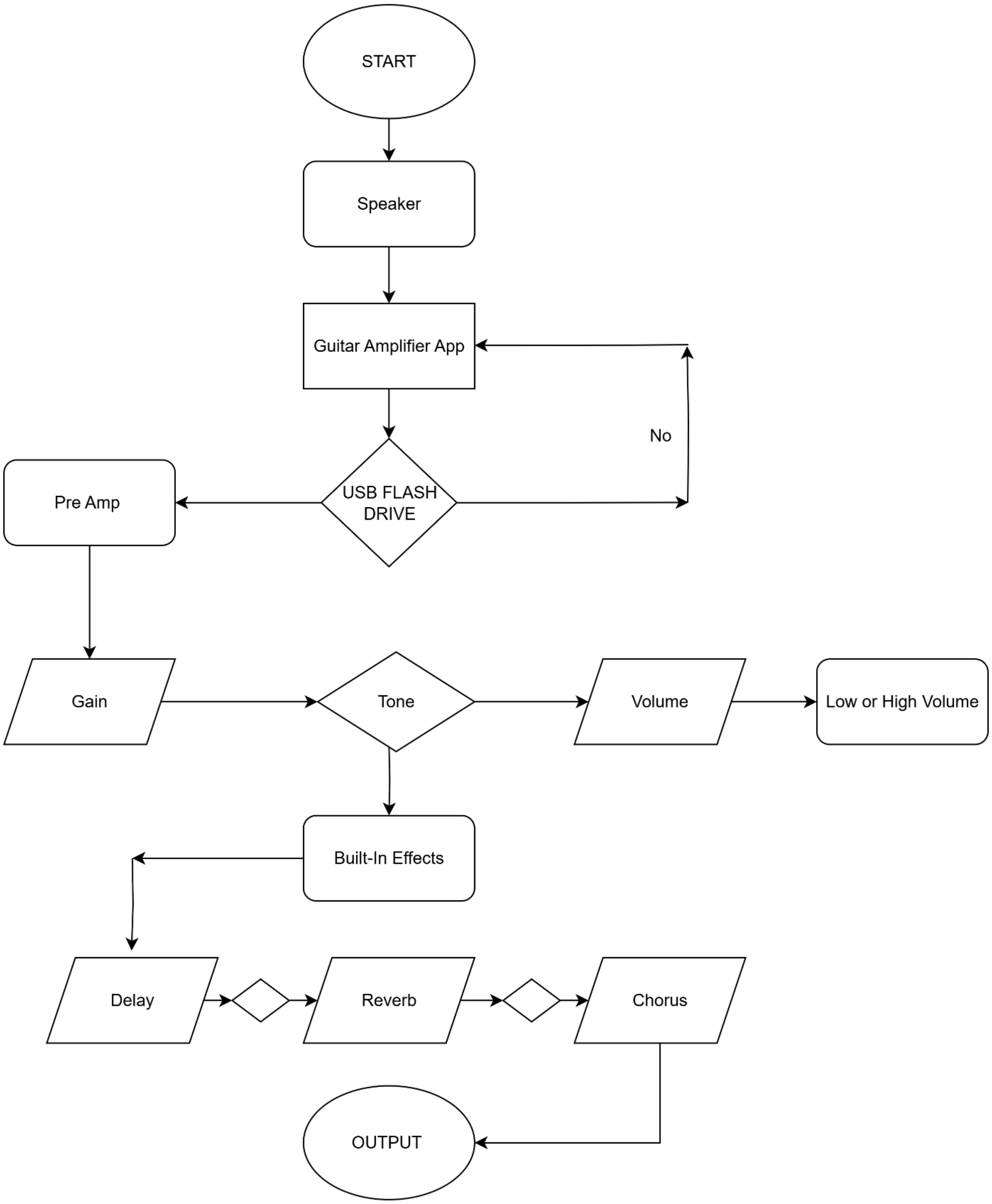

Figure 3.9 Flowchart

3.6 Data Flow Diagram

3.7 Research Instrument and Data Treatment

3.7.1 Respondents Demographic Profile

A respondent's demographic profile typically includes characteristics like age, gender, ethnicity, income, education, occupation, and marital status, providing a snapshot of the individuals participating in a study or survey.

3.8.2 Research Instrument

A Research Instrument is a tool used to collect, measure, and analyze data related to your research interests. Your research instrument must be paralleled to your objective so that it will be easier to prove your objective. You may use the different standardized questionnaires like the ISO standards and IEEE standards and many others.

Table 3.1 shows the System Usability Scale (SUS) survey form. The SUS is a 10-item standardized questionnaire that is used in measuring the usability of the system.

Table 3.1: User Usability Scale