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# DESIGN AND MANUFACTURING OF A CUSTOM GUITAR AMPLIFIER: OPTIMIZING MATERIALS FOR ACOUSTIC PERFORMANCE AND DURABILITY

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## ABSTRACT

*The project sought to design a guitar amplifier that would easily integrate into the decor of an apartment, imitating a piece of furniture. The design aims to create an aesthetic appearance that fits harmoniously in different types of homes, eliminating the need to bend down to adjust volume, tone, etc. The amplifier was built from a wooden case, with an accessory storage system in a lower drawer, and the functionality was achieved by integrating an Arduino board and a PCB circuit to implement the audio effects. The study details the stages of designing the amplifier prototype, including making the printed circuit board and processing the audio signal in four distinct stages: analogue signal amplification, digital processing by Arduino, signal output stage, and power supply. The project also includes the careful design of the amplifier components, using quality materials such as spruce panel to ensure superior acoustics. The result demonstrates the complexity and innovation in the field of musical equipment, combining aesthetic with technical aspects.*

KEYWORDS: custom guitar amplifier, acoustic performance, industrial design

## 1. Introduction

Guitar amplifiers generally have a design that does not easily blend into the decor of an apartment room. Amplifiers have evolved exponentially over time, resulting in a great diversity of products for both amateurs and professionals. The market is extensive, catering to the most demanding requirements, while also offering products for those on a budget. Most of today’s products, regardless of category and budget, have a professional look strictly geared toward use in a recording studio or rehearsal room [1].

Another important aspect is the height of a combo guitar amplifier, which is low, requiring the user to bend down to adjust volume, tone, etc.

This project aims to combine the appearance of a furniture piece with the functionality of an audio system with guitar effects (Fig. 1). The components will be housed in a wooden casing, with the height of the entire system adjusted so that bending down is unnecessary, and a drawer for accessory storage will be included at the bottom.

In the following study, we will discover how to design a guitar amplifier that can easily integrate into apartment decor by being disguised as a piece of furniture. Additionally, the size will be adjusted to make amplifier controls more accessible to the user. The project will seek to integrate elements like an Arduino board together with a PCB circuit to implement amplifier functionality and add various effects through these circuits.

Guitar amplifiers are complex products requiring careful design, both functionally and aesthetically. Their characteristics can vary by manufacturer, each having the freedom to express their vision through the product and incorporate various types of effects and programs.

A guitar amplifier is made up of several components that work together to amplify and process sound: the preamplifier is the first section where the signal from the guitar is amplified, also offering the possibility of adjusting the frequencies (high→medium→low) and applying effects such as

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distortion or reverberation [2]; the tone correction, placed before the final amplification stage, that allows the frequencies and tone of the signal to be adjusted; the amp also includes effects, which can change the shape of the waveform (i.e. distortion and fuzz) or add delay (echo or reverb); the final amplifier increases the power of the processed signal so that it is effectively played through the speaker, which in turn converts the electrical signal into sound. All these components are mounted on printed circuit boards (PCBs), and amplifiers can be built by various methods (Point to Point, Tag/Turret Board, PCB) to meet different performance and cost requirements [3].

Wood is prized as a material for amplifier enclosures due to its unique acoustic properties, which is why often is used in both musical instrument manufacturing and performance halls, where it contributes to superior sound quality. In the case of musical instruments, wood is preferred for its resonance, which improves tone quality, and in performance halls, also wood amplifiers can transmit sound efficiently, providing a quality listening experience [4].

Instruments like guitars, violins and pianos contain a type of sound box that is meant to amplify the sound of the strings. The vibrations are captured inside the box, and the tone emitted is influenced by the type of wood used. Each type of wood offers unique tones, having the properties of resonance, porosity and density that affect the sound. For example, spruce produces a "clear" tone, mahogany a "rich and warm" tone, maple a "concentrated" tone, and rosewood is known for sustaining low notes.

In the case of guitar amps, opinion is divided on the impact of construction on tone. A significant element is the speaker, whose materials and dimensions influence the tone. Materials used to build amplifiers include plywood, MDF and chipboards. Birch plywood, often found in speaker boxes, resonates better than MDF and chipboard, providing a "powerful and lively" tone, increased resistance to moisture. MDF is durable and heavy but does not add a "live" resonance to the sound, while chipboard is denser and cheaper, but less durable.

There are, however, many subjective opinions regarding the tone of amplifiers, and their impact on tone is difficult to quantify objectively.

In experimental studies, tests were carried out to observe the influence of the material on the tone. One of the studies looked at whether the type of box material (plywood, MDF, chipboard) affects the sound, using the same size and speaker [5]. The recordings, made without indicating the material used, showed that auditory differences were almost nonexistent, indicating a possible psychological effect in pitch perception [5].

A second reference study focused on box construction and size differences (1x12, 2x12, 4x12), showing that the back of the box (open or closed) affects low frequencies below 200 Hz, and box size influences the tone [6].

The third study compared Fender, VOX, and Marshall amplifiers, revealing that the order of components in each circuit contributes to differences in tone [7].

## 2. Custom amplifier prototype design

For this project, the code sequence and circuit layout from ElectroSmash were used [8], with some modifications to make the assembly compatible with the product propose.

### *2.1. PCB board design*

The first step in creating this prototype is to develop the electronic circuit that will contain the audio signal manipulation elements, specifically the effects. The "Press-n-Peel" or PnP method was used to create the circuit board, as it is the most popular due to its simplicity. Is easy to perform, low–cost, and provides good accuracy.

The steps to create the printed circuit board (see Fig. 2):

- Printing the circuit layout on the PnP sheet (the circuit layout was printed on a glossy A4 sheet using a laser printer with toner);
- Cutting the fiberglass board and trimming the layout (a cutter was used to remove the unused paper, and the board was cut to the layout's dimensions using a saw);
- Transferring the layout onto the board (the PnP sheet was heated with an iron and pressed onto the board to transfer the toner, thus printing the circuit onto the copper foil);
- Sodium persulfate bath (the printed board was immersed in a sodium persulfate solution until the unprinted copper areas dissolved);
- Cleaning with acetone (after the copper was completely removed from the unprinted surfaces, the board was taken out of the sodium persulfate bath, and the printed side was cleaned with acetone, leaving the copper circuit intact);
- Drilling the board (after completing the circuit printing, holes were drilled for mounting the electronic components and connections using a drill);

Soldering the components (finally, the electronic components were soldered onto the board using a soldering iron to secure the parts and ensure electrical connections).

Audio Signal Processing of the assembly is divided into four distinct stages (see Fig. 3):

- Analog Input Stage − the low-amplitude signal from the guitar pickup is amplified, filtered, and prepared to be read by the analogue–to–digital converter or ADC in the Arduino Mega processor;
- Arduino Mega Stage − receives the digital signal from the ADC, thus, it processes according to the programmed sequence (distortion, fuzz, delay, etc.);
- Output Stage − the processed signal in the Arduino Mega stage is output through two PWM outputs, resulting in an analogue audio signal that passes through a tone correction (bass, midrange, and treble) before entering the amplification stage;
- Power Supply Stage − provides power voltages of +15V and -15V for the input and output stages and a 9V power supply for the Arduino processor.

The operation of the assembly is as follows: the first operational amplifier in the input stage prepares the analogue signal for conversion to a digital signal by amplifying and filtering the sinusoidal signal from the guitar; the second operational amplifier in the output stage receives the signal from the Arduino Mega processor through two 8-bit PWM outputs, which it combines to produce an analogue signal.

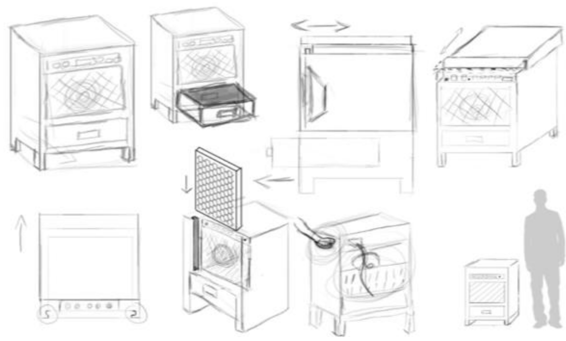

***Fig. 1.*** *Concept sketch of the custom amplifier*

The user interface consists of two configurable momentary switches that allow switching from one effect to another and adjusting levels for certain effects, a toggle switch that changes the mode between effect scrolling or level adjustment, and an OLED display that shows the selected effect or its level. The Arduino Mega connectors link the board with the analogue stages to the board with the Arduino Mega processor. The connection is made through male–female pin lines.

The code sequence for the amplifier was sourced from the ElectroSmash website, specifically from their documentation on the pedalSHIELD MEGA Arduino Guitar Pedal project [8]. This code sequence has been adapted and customized to meet specific project requirements, ensuring optimal integration between components and facilitating precise, real-time control of effects and audio signal level. Thus, the user can easily navigate through the effects and adjust their parameters, benefiting from an interactive and intuitive experience, all functions being accessible through the simplified interface.

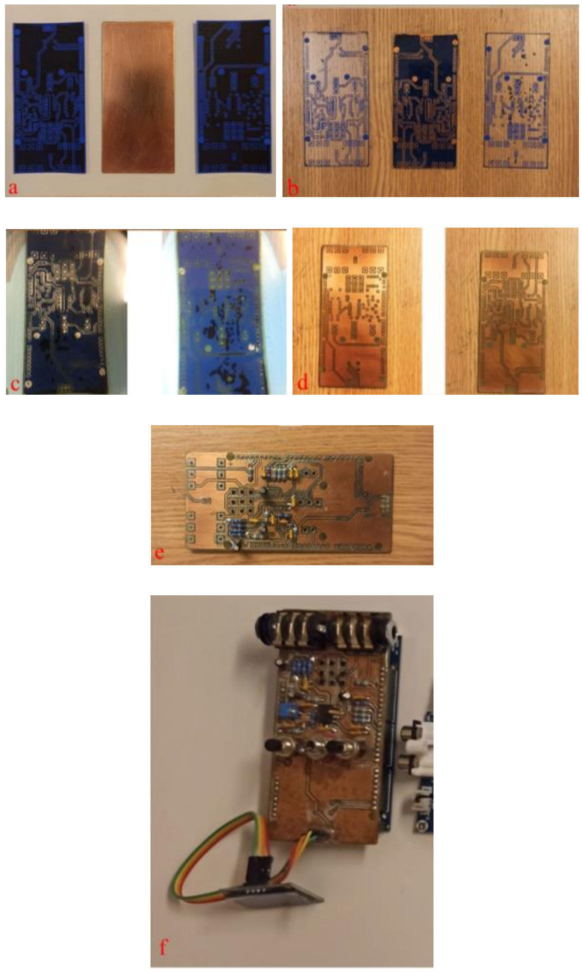


***Fig. 2.*** *PCB manufacturing: a. Cutting the printed circuit board and trimming the schematic; b. Printing the circuit layout; c. Etching the copper; d. Board cleaning with acetone; e. The board along with various components; f. The completed board inserted into amplifier assembly*

### *2.2. Component design method*

Autodesk Inventor Professional 2024 software was used to design the elements of the amplifier, as shown in Fig. 4.

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The product requires the following elements: the walls of the box, namely two side plates and one top plate, the drawer parts (total 5 elements), the interface support together with the circuit support shelf, the speaker support, another support shelf, the outer cover that will support on said shelf, 2 drawer supports and a back cover. These components have been designed to ensure both structural stability and easy accessibility to all internal amplifier modules, allowing for efficient assembly and simplified maintenance.

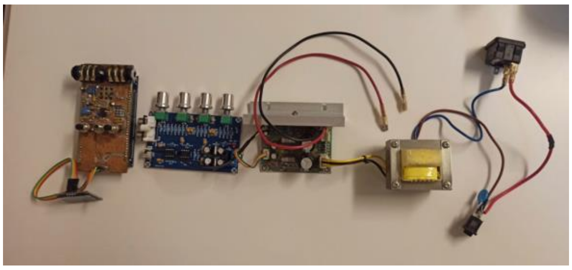

***Fig. 3.*** *The electronic elements used*

Each element is designed individually and introduced for design verification.

In the case of this project, an 18 mm spruce panel thickness, with dimensions of 3000 x 1220 mm was used, from which the parts necessary for the product were cut.

To obtain the final product, a series of processes were carried out (Fig. 5):

- To begin with, the pieces were framed on the panel, an operation performed on the computer using the Optim Cut program.
- Cutting subassemblies, operation performed on circular saw. The circular saw is fitted with a blade that has special Vidia teeth for cutting softwood.
- The joining of subassemblies is done with 8 mm diameter wooden dowels and 15 mm diameter eccentric cams.
- The holes are made on the multi–drilling machine (is a machine that can make 20 holes at the same time).
- The next step is sanding – the sanding operation is very important, it must be done very carefully, because a good sanding leads to obtaining a uniform and pleasant surface after varnishing. Sanding is performed on an abrasive belt machine. In this project we start sanding with 100–grit abrasive, then switch to a smaller grit, i.e. 150.
- The first time after sanding, the parts are "blown" with compressed air to remove dust and wiped easily with a damp cloth.

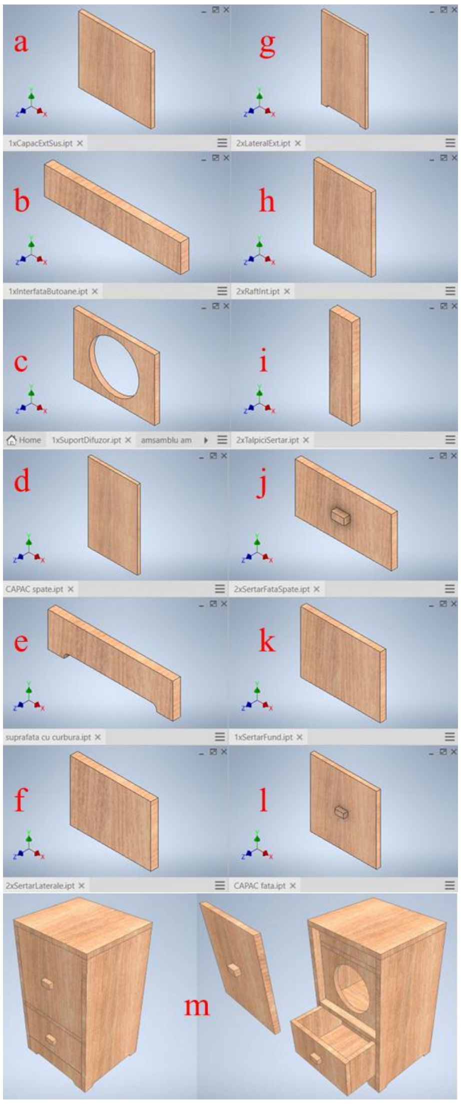


***Fig. 4.*** *Amplifier case design: a. box cover; b. button interface; c. speaker support; d. back cover; e. curved surface; f. drawer sides; g. box side; h. shelf; i. drawer bottom pieces; j. drawer front; k. drawer base; l. front cover; m. prototype assembly*

- A primer layer is applied – the primer has the role of covering the pores. After the primer has dried (approximately 2 hours), we continued sanding the surfaces with 150-grit abrasive. After sanding the primer, the surfaces are inspected, and where there are knots, marks in the wood, etc., the respective area is grouted with wood putty. It is left until the grout dries and the grouted tiles are sanded.
- Then the varnish was applied and let to dry – we sand the parts after the varnish has dried using an abrasive less than 180-grit.

• Varnish again, we left to dry, then sand the parts with 240-grit abrasive. After drying, the last layer of varnish was applied, and the parts are ready. Priming and varnishing are done using a compressed air paint gun with a 1.5 mm nozzle.


***Fig. 5.*** *Processing stages of the wooden amplifier case: a. Circular saw for material cutting; b. Eccentric cam for fastening; c. Wood dowels for fastening; d. Belt sander; e. Spray gun*

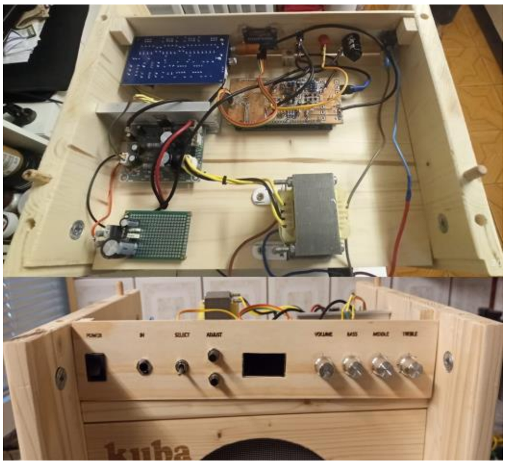

***Fig. 6.*** *Final assembly of the amplifier*

Finally, the electronic parts are mounted in the created assembly, and the product is completed (see Fig. 6).


***Fig. 7.*** *The final design of the custom amplifier*

## 3. Conclusions

The purpose of this study, thus, was to design a guitar amplifier that could be integrated easily into an apartment environment, going unnoticed, being easily confused with a piece of furniture. The main goal was to create an aesthetic design that harmoniously can integrate into various types of homes. Guitar amplifiers will always remain products with high complexity both functionally and aesthetically, being an indispensable object for music enthusiasts.

The study emphasizes the potential for innovation in musical equipment by combining the aesthetic and technical aspects.

## References

**[1]. Hunter D.**, *The Guitar Amp Handbook: Understanding Tube Amplifiers and Getting Great Sounds*, Rowman & Littlefield, 2023.

**[2]. Pakarinen J., David T. Y.**, *A review of digital techniques for modeling vacuum-tube guitar amplifiers*, Computer Music Journal 33.2, p. 85-100, 2009.

**[3]. Carter B.**, *The PCB is a component of op amp design*, Analog application journal, http://www. ti. com/sc/docs/apps/msp/journal/aug2000/aug_09. pdf (2000).

**[4]. Keeports D.**, *The warm, rich sound of valve guitar amplifiers*, Physics Education, vol. 42, no.2 IOP Publishing Ltd, DOI 10.1088/1361-6552/aa57b7, 2017.

**[5]. *****, *Is Guitar Cabinet Tone Wood a Thing?* (Mar. 03, 2022), online video, Available at https://www.youtube.com/watch?v=fCnJT1pT7YM, accessed on Jan. 17, 2024.

**[6]. *****, *Tested: Where Does the Tone Come from in a Speaker Cab?* (May 23, 2022), online video, Available at https://www.youtube.com/watch?v=-eeC1XyZxYs, accessed on Jan. 17, 2024.

**[7]. *****, *Tested: Where Does the Tone Come from in a Guitar Amplifier?* (Oct. 03, 2022), Available at https://www.youtube.com/watch?v=wcBEOcPtlYk, online video accessed on Jan. 17, 2024.

**[8]. *****, ElectroSmash - pedalSHIELD MEGA Arduino Guitar Pedal, online, Available at https://www.electrosmash.com/pedalshield-mega, accessed on Jun. 10, 2024.

**[9]. Gherman L. G., Sandu I., Vasilache V.**, *New Materials to Support the Preservation of Old Wood Used for Art Objects*, The Annals of "Dunarea de Jos" University of Galati. Fascicle IX, Metallurgy and Materials Science 34.2, p. 20-24, 2011.

**[10]. Kubaszky A. E.**, *Proiectarea unui amplificator pentru chitară*, Dissertation Thesis, 2024.