Internship Project Report

Title: 2-Layer PCB Design for Half-Bridge Class D Bluetooth Audio Amplifier

1. Project Overview

This project focused on the schematic design and PCB layout of a **Class D audio amplifier** using a **half-bridge topology** on a **2-layer PCB**. The amplifier is capable of driving a speaker with high efficiency, using **Pulse Width Modulation (PWM)** techniques to amplify the audio signal. A key feature of the system is the integration of the **MHM-28 Bluetooth module**, which enables wireless audio streaming. The project involved extensive work in analog and digital electronics, filter design, power electronics, and PCB layout using KiCad.

2. Why Class D Amplifier?

The amplifier design employs a **Class D topology**, which is known for:

- **High Efficiency**: Typically >90%, due to transistors operating as switches rather than linear amplifiers
- **Compact Size**: No need for large heatsinks or power-hungry biasing components
- **Low Heat Dissipation**: Minimal energy lost as heat, important for embedded and portable systems
- **Suitability for Wireless Audio Systems**: Efficiency and size are critical in battery-operated or space-constrained environments

In contrast to Class A, B, or AB amplifiers, Class D operates transistors in either full-on or full-off states, drastically reducing power loss and improving overall efficiency.

3. Why Half-Bridge Topology?

The choice of **half-bridge topology** was motivated by several key advantages:

- **Fewer Components**: Only two switching transistors required, reducing cost and complexity
- **Simpler Gate Drive**: Easily implemented with a dedicated driver like the IRS2113
- **Compact Design**: Ideal for 2-layer PCBs with limited space
- **Single-Supply Operation**: Suitable for unipolar speaker connections

While full-bridge topologies provide differential output and potentially higher power, they also require more components and increased design complexity. For this application, the half-bridge met all performance and efficiency requirements.

4. System Block Diagram Overview

Block	Function
Power Supply	Provides 5V and 12V rails via linear regulators
TLC555 Timer	Generates a triangle waveform for PWM modulation
LM393 Comparator	Compares audio input with reference waveform to create PWM
74HC04 Inverters	Insert dead time and shape signals
IR2113 Driver	Drives high-side and low-side MOSFETs
IRLZ44N MOSFETs	Perform power switching to drive speaker load
LC Filter	Reconstructs audio from PWM output
MHM-28 Module	Receives Bluetooth audio input

5. Bluetooth Interfacing with MHM-28 Module

The **MHM-28 Bluetooth module** enables seamless audio streaming from devices such as smartphones or laptops. Key features include:

- Bluetooth V4.0 with A2DP profile
- Stereo analog audio output
- Compact and low-power design
- Simple integration via header pins

In this project, the stereo output is connected to the inverting input of the comparator (LM393), where it is modulated against a reference triangle waveform to create a PWM representation of the input audio signal.

6. Power Supply Design

Two linear regulators were used:

- **LM7805 (U5)**: Provides a regulated 5V supply for logic-level devices and control circuitry
- **LM7812 (U6)**: Supplies a stable 12V rail required for the IRS2113 gate driver and MOSFET switching

The regulators are stabilized with decoupling capacitors:

- Input: 47µF electrolytic
- Output: 47µF electrolytic + 220nF ceramic (for high-frequency stability)

7. PWM Generation and Signal Conditioning

The TLC555 timer is configured in astable mode to generate a triangle or sawtooth waveform. This waveform is fed to one input of the LM393 comparator. The other input receives the analog audio signal (from MHM-28), resulting in a PWM signal whose duty cycle varies according to the audio amplitude.

To ensure proper switching and protect the MOSFETs, **dead time** is introduced using **74HC04 inverters** to delay signal edges and prevent shoot-through currents.

8. Driver and Switching Stage

The IRS2113 high- and low-side driver IC is responsible for:

- Driving the gates of the IRFZ44N MOSFETs
- Level-shifting logic signals to 12V gate control
- Ensuring proper timing and dead-time insertion between high-side and low-side switching

The IRFZ44Ns were chosen for their:

- Fast switching times
- High current capacity
- Low Rds(on) for efficient conduction

9. LC Output Filter Design and Calculations

To convert the PWM back into an analog signal, an **LC low-pass filter** is employed.

Filter Type*: Parallel LC configuration*

This configuration resonates at the desired cutoff frequency, shunting high-frequency switching components to ground.

Target Cutoff Frequency*:*

The desired cutoff frequency was chosen to be: (f_c , ,)

This ensures:

- Audio frequencies (<20 kHz) are passed
- Switching frequencies (~200 kHz) are effectively attenuated

Component Values*:*

- **L = 16.5 µH**
- **C = 1.03 µF**

***Formula**:*

$(f_0 = 1/2\pi(\sqrt{LC}))$

Substituting the values: $(f_0 = 38.6\text{KHz})$

This confirms that the parallel LC filter is correctly tuned to the switching frequency region, offering excellent attenuation of unwanted harmonics.

10. PCB Layout and Implementation

The circuit was implemented on a **2-layer PCB**, with careful consideration for:

- **Grounding and decoupling**: Ground planes and bypass capacitors placed close to ICs
- **Minimized loop area**: Power and signal paths routed efficiently to reduce EMI
- **MOSFET layout**: Placed near driver for minimal gate trace delay
- **Bluetooth module**: Socketed for ease of debugging and modularity

The design was completed using **KiCad**

11. Results and Observations

Parameter	Value
Efficiency	>90%
Max Output Power	~10–20W depending on load and supply
Cutoff Frequency	38.6 kHz
PCB Layers	2
Bluetooth Streaming	Supported via MHM-28

12. Conclusion

From the project the following key outputs can be obtained:

- Understanding of Class D amplifier theory and implementation
- Practical experience with analog comparator circuits and PWM control
- Hands-on design and routing of a 2-layer PCB for mixed-signal systems
- Integration of wireless streaming modules (MHM-28)
- Development of skills in power electronics, filter design, and circuit layout

The amplifier successfully achieved clean, efficient audio amplification with wireless control, suitable for both portable and fixed audio applications.