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Original Article

Design and Construction of a 100-Watt Class AB Audio Amplifier

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Abstract - The amplifier device increases the amplitude of a signal waveform without changing other parameters of the waveform, such as frequency and wave shape. Audio amplifier amplifies an electrical signal that has a frequency range corresponding to the range of human hearing, which is 20 Hz to 20 KHz. This work seeks to design and construct a 100-watt class AB audio amplifier using a D718 power transistor. The design is in four stages, which are the power supply unit, signal processor unit (input stage), power amplifier unit (amplification stage), and output unit (output stage). The calculated power for this audio amplifier was 99.9 watts. The gain of the amplifier is 9.62 dB, which shows that the amplifier has a low signal-to-noise ratio; the results obtained show that the developed amplifier worked satisfactorily. An input frequency of 70 Hz given to the amplifier by the frequency generator yields an output frequency of 166.6 Hz. It implies that the output signal is twice the input signal, meaning that there is amplification with the amplifier that the amplifier works is satisfactory. Self-designed and self-constructed amplifiers are safer, and they can give the required output. Based on the power level this is cheap, more reliable and more effective to use. The transistors emit less heat when the power amplifier is powered ON; this is because the heat sink was reasonably thick enough to handle the power dissipated by the transistors.

Keyword - Audio amplifier design, Class AB amplifier, Power transistor D718, Signal amplification.

1. Introduction

Many centuries ago, people found it difficult to be heard over a few meters away from their standing position while addressing an audience. This motivates the need to look into a technology that will increase reliability and efficiency in addressing a large crowd. Amplifiers are electronic devices that boost or strengthen an input signal. In other words, they provide amplification [1, 2]. The nature of the signal could be of any type such as voltage, current or power of a circuit. There are many different types of electronic circuits classed as amplifiers, from operational amplifiers to small signal amplifiers up to large signal and power amplifiers [3, 4].

Sound is an energy or wave made up of vibration; when an object vibrates, it causes flow in the air particles. When these particles collide with each other, this makes them vibrate [5]. This flow is called sound waves, and these waves keep on going until they run out of energy [5]. In some cases, sound with low energy will be low and not audible, to increase the energy of the sound, Amplifiers are preferred [6, 7]. The terms amplifier and amplification were derived from a Latin word called *amplificare*, to enlarge or expand [8]. An Amplifier is an electronic device used to increase the amplitude of a signal waveform without changing other parameters of the waveform, such as frequency or wave shape [10-13].

Audio range is the range of frequencies that the human ear can hear and perceive. The range for human hearing extends from 20 Hz to 20 kHz [14]. Audio amplifiers amplify electrical signals that have a frequency range corresponding to the range of human hearing, which is 20 Hz to 20 kHz, to a level suitable for driving loudspeakers [14, 15]. An amplifier is a device that can increase the power of a signal (a time-varying voltage or current). It is a two-port electronic circuit that uses electric power from a power supply to increase the amplitude of a signal applied to its input terminals, producing a proportionally greater amplitude signal at its output [16, 17]. The amount of amplification provided by an amplifier is measured by its gain. It is a circuit that has a power gain greater than one [18, 19]. Audio power amplifier, which is also known as an audio amplifier, is a kind of electronic amplifiers that amplify low-power audio signals, such frequencies of the low-power signals are always between 20 Hz to 20 KHz for human hearing to a level that can be suitable for driving the loudspeakers [14]. It does this by taking energy from a power supply and controlling the output to match the input signal shape but with a larger amplitude [14]. There are many forms of electronic circuits classed as amplifiers, from Operation Amplifier and Small Signal amplifiers up to Large Signals and Power amplifiers [20, 21].

Amplifier circuits form the basis of most electronic systems, many of which need to produce high power to drive some output device [22]. An Audio amplifier normally has output power from less than one watts (1 W) to several hundred Watts (>100 W). Therefore, it is necessary to produce a good-quality loud sound. There are four basic types of amplifiers in the electronic field, namely, the voltage amplifier, the current amplifier, the Trans-conductance amplifier and the Trans-resistance amplifier. Amplifiers can be thought of as a simple box or block containing the amplifying devices and components, such as transistors, Field Effect Transistors (FET) or Operation Amplifiers (Op-Amp), which have two input terminals with the output signal being much greater than the input signal as it has been amplified.

The different classes of amplifiers are Class A, Class B, Class C, Class D, Class E, Class F, Class G, Class H, and Class AB [23]. Power amplifier circuits with output stages are classified as A, B, AB and C for analog designs and class D and E for switching design; the working of an amplifier is based on the proportion of each input cycle (conduction angle) during which an amplifying device passes current [24, 25].

Class A Amplifier has a low efficiency of less than 50% but good signal reproduction and linearity [26]. Class B Amplifiers are twice as efficient as Class A Amplifier with a maximum theoretical efficiency of about 70% [27]. Class AB amplifier has an efficiency rating between that of Class A and Class B but poorer signal reproduction than Class A amplifiers [28]. Class C Amplifier is the most inefficient amplifier class as only a very small portion of the input signal is amplified; therefore, the output signal bears very little resemblance to the input signal. Class C Amplifiers have the worst reproduction [29]. Class D operations have an output efficiency of around 90%, allowing high-power output without the need for such high-power transistors and elaborate heat sinks. Class D amplifier is a very efficient class of amplifier suited for both high-power audio, RF amplifiers and low-power portable amplifiers. Class E and F amplifiers are highly efficient switching power amplifiers. Class G amplifier aims to reduce the amplifier power dissipation, it is very useful in large Public Addressing amplifiers [30].

The audio stereo power amplifier is designed to deliver power to the load (speaker). It is the product of the voltage and current applied to the load, with the output signal power being greater than the input signal power [31, 32]. In other words, a power amplifier amplifies the power of the input signal, which is why these types of amplifier circuits are used in audio amplifier output stages to drive loudspeakers. The power amplifier works on the basic principle of converting the DC power drawn from the power supply into an AC voltage signal delivered to the load [33]. Although the amplification is high, the efficiency of the conversion from the DC power supply input to the AC voltage signal output is usually poor. The preceding stages in such a chain are low-power audio amplifiers, which perform tasks like pre-amplification (this is particularly associated with record signals); amplifiers require these low-level inputs to adhere to line levels. While the input signal to an audio power amplifier may measure only a few hundred microwatts, its output may be tens or hundreds of watts for a home system or thousands or tens of thousands of watts for a concert sound reinforcement system [34]. Not all amplifiers are the same and are therefore classified according to their circuit configurations and methods of operation. In electronics, small signal amplifiers are commonly used devices as they have the ability to amplify a relatively small input signal, for example, from a sensor such as a photo device, into a much larger output signal to drive a relay, lamp or loudspeaker [35, 36]. The classification of an amplifier depends upon the size of the signal, large or small, its physical configuration and how it processes the input signal, which is the relationship between the input signal and current flowing in the load.

2. Materials and Methods

This section discusses the analysis, design and implementation of the 100 W class AB audio amplifier. Factors such as availability and accessibility of materials, durability, robustness and functionality of the design such that the desired result is obtained at any time the system is energized. The steps that were taken to design this project include:

(i) Selection of components: Table 1 shows the description of the components used in this research.

Table 1. List of components and description

S. No.	Components / Equipments	Quantity	Values / Description
1	Transistor	4	D718
2	Resistor	1	1kΩ
3	Variable Resistor	1	100kΩ
4	Capacitor	1	1000μf/16V
5	Heat Sink	1	
6	Audio Jack	1	3.5mm
7	Inductor	1	200turns
8	Speaker	1	100W, 8Ω
9	Power Source (12 Volt Charger)	1	12V

(ii) Methods used in the design, circuit construction and testing.

The methods used in the design and construction of this 100-watt class AB audio amplifier are categorized into stages, which include:

2.1. Stage One: Simulation

Simulation of the circuit diagram was done using an electronic workbench called livewire software. The livewire is a platform used to design circuit diagrams by obtaining the components to be used from the component gallery of components. Connections were made starting with the power supply and progressing through the signal input, transistor and output stages. To ensure accuracy and precision, careful attention was given to each terminal. With the circuit connected according to the diagram, the next step was to run the simulation. Pressing the "Run Simulation" option revealed the expected output, confirming the accuracy of the design. Figure 1 shows the schematic circuit diagram of the audio amplifier used in this work, and Figure 2 shows the simulated circuit design using the livewire software.

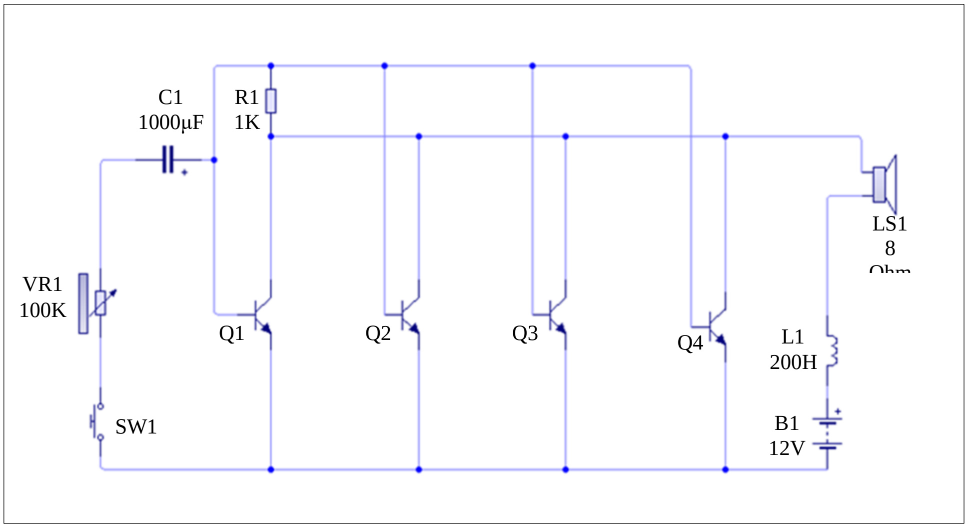

Fig. 1 Schematic circuit diagram of the audio amplifier

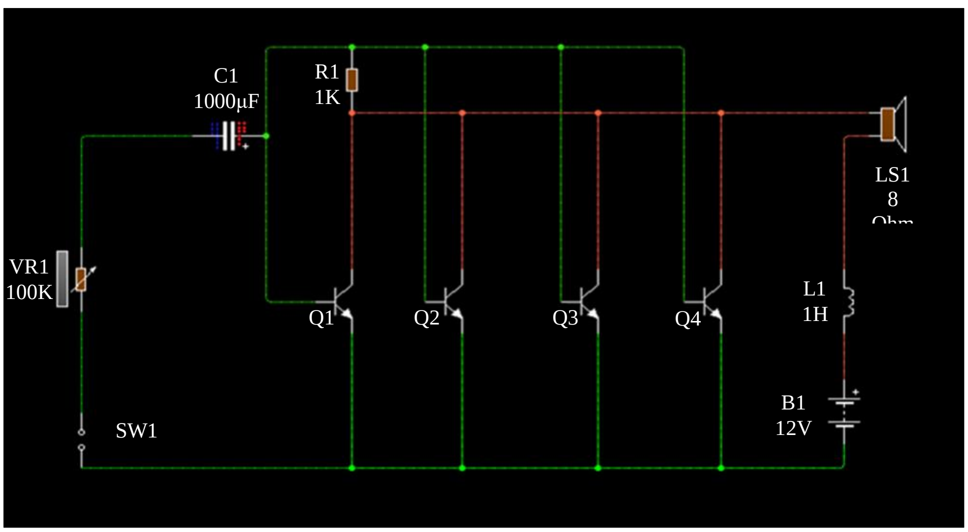

Fig. 2 A successful simulated circuit design using the livewire software

2.2. Stage Two: Assembling and Test Running on the Vero Board

The four transistors were connected to a heat sink, wiring each terminal back-to-back (base-to-base, collector-to-collector, and emitter-to-emitter). A feedback loop was created by connecting the collector terminal of the first transistor to its base terminal via a 1K resistor. A 1000μf capacitor was added in parallel with the resistor. A variable resistor in series with the capacitor was also installed, linking it to one terminal of the audio jack.

The other audio jack was connected to the emitter terminal, and then linked the emitter terminals to the negative power supply source. Connected the power supply source to the inductor, then to the positive speaker terminal. Finally, the collector terminal of the fourth transistor was connected to the negative speaker terminal. With all connections in place, power was applied to the amplifier, as shown in Figure 3.

Fig. 3 Assembling and test running on vero board

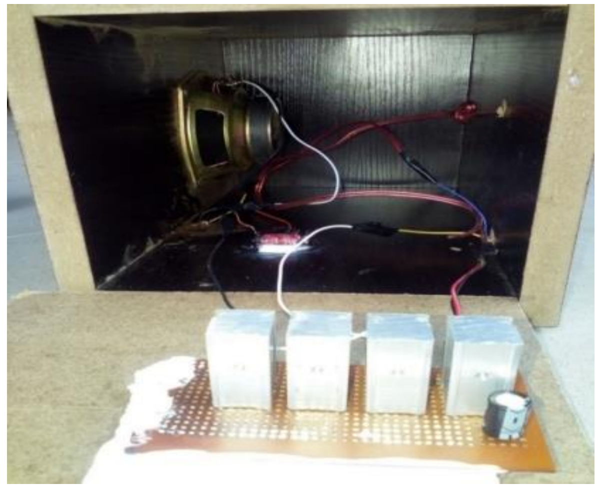

Fig. 4 Soldering of components on the vero board

Fig. 5 Guming the component to the casing

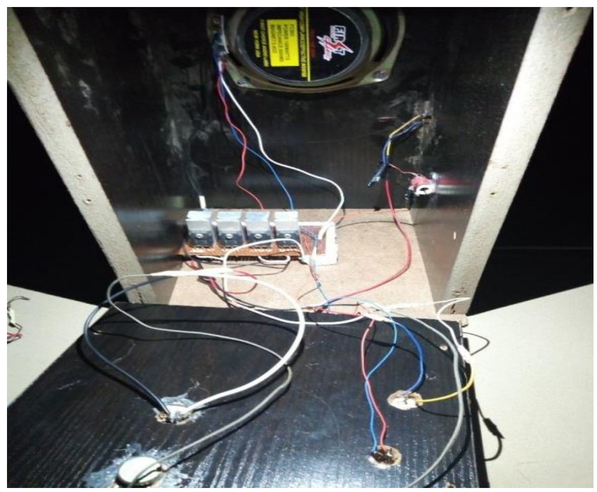

Fig. 6 Dressing of the conductor to its appropriate pots

2.3. Stage Three: Soldering, Testing and Packaging

When assembling the circuit on the vero board, the functionality of each component was verified with a multimeter, and they were also inserted into the vero board carefully before soldering to avoid overheating and potential damage to components, as shown in Figures 4, 5, and 6.

3. Results and Analysis

The results for the design and construction of the audio amplifier are in two parts. Part one is from the values obtained from the simulation of the circuit design, which are shown in Tables 2, 3, 4, and 5. Part two is from the values obtained from the use of a multi-meter, which is shown in Table 6.

Table 2. Input and output current, voltage and power (simulated)

S. No.	Parameter	Input	Output
1	Current (mA)	770.43	770.43
2	Voltage (V)	11.91	5.74
3	Power (W)	9.17	4.42

Table 3. Base current, voltage and power

S. No.	Parameter	Base current I_B (mA)	Base voltage V_B (mV)	Base power (mW)
1	Transistor 1	1.21	910.89	1.10
2	Transistor 2	1.21	910.89	1.10
3	Transistor 3	1.21	910.89	1.10
4	Transistor 4	1.21	910.89	1.10

Table 4. Emitter current, voltage and power

S. No.	Parameter	Emitter current I_E (mA)	Emitter voltage V_E (V)	Emitter power (W)
1	Transistor 1	192.61	2.12μ	4.08×10^{-7}
2	Transistor 2	192.61	1.93μ	3.71×10^{-7}
3	Transistor 3	192.61	1.54μ	2.96×10^{-7}
4	Transistor 4	192.61	0	0

Table 5. Collector current, voltage and power

S. No.	Parameter	Collector current I_c (mA)	Collector voltage (V)	Collector power (W)
1	Transistor 1	191.40	5.74	1.09
2	Transistor 2	191.40	5.74	1.09
3	Transistor 3	191.40	5.74	1.09
4	Transistor 4	191.40	5.74	1.09

Table 6. Input and output current, voltage and power (multi-meter)

S. No.	Parameter	Input	Output
1	Current (mA)	99.6	5.6
2	Voltage (V)	11.98	4.34
3	Power (W)	1.19	0.02

Table 6 shows the result of the input and output voltage, current and power of the amplifier as obtained using the multi-meter.

Calculations from the measurement using the values obtained from Table 2 are as follows,

$$\text{Voltage gain} A_v = \frac{V_{out}}{V_{in}} = \frac{5.74}{11.91} = 0.48 \quad (1)$$

$$\text{Current gain } A_i = \frac{I_{out}}{I_{in}} = \frac{770.43\times10^{-3}}{770.43\times10^{-3}} = 1$$

$$\text{Input power } P_{in} = I_{in}V_{in} = 11.91 \times 770.43 \times 10^{-3} = 9.175 \text{ W}$$

$$\text{Output power } P_{out} = I_{out}V_{out} = 5.74 \times 770.43 \times 10^{-3} = 4.422 \text{ W}$$

$$\text{Gain} = \frac{P_{out}}{P_{in}} = \frac{4.422}{9.175} = 0.481$$

To obtain the value of the gain in decibels, given that;

dB= $10log_{10}(\frac{P_{out}}{P_{in}})^2 = 20log_{10}(\frac{P_{out}}{P_{in}})$ (2)

dB= $20log_{10}$ (0.481)

Gain = 9.62 dB

Calculations from the measurement using the value obtained from Table 6 (multi-meter reading) are as follows:

Input current I_{in} = 99.6 mA = 99.6 × 10^{-3} A

Input voltage V_{in} = 11.98 V

Input power $P_{in} = V_{in}I_{in}$ = 11.98V × 99.6 × 10^{-3}A = 1.19W

Output current I_{out} = 5.6mA = 5.6 × 10^{-3}A

Output voltage V_{out} = 4.34 V

Output power P_{out} = 4.34V × 5.6 × 10^{-3}A = 0.02 W

Resistivity is given as V=IR, where V=11.98V and I= 99.6 × 10^{-3}A

Therefore $R=\frac{V}{I}=\frac{11.98V}{99.6\times10^{-3}A}$ = 120.28 Ω ≡ 120 Ω (3)

Obtaining the power of the amplifier, in general, is given as:

P = IV or $\frac{V^2}{R}$, where p =100 W, I =? V = 11.98 V

Using P = IV (4)

$I=\frac{P}{V}=\frac{100}{11.98}$ = 8.34 A

Also

$P=\frac{V^2}{R}=\frac{(11.98)^2}{R}$

$100=\frac{143.5}{R}$, $R=\frac{143.5}{100}$ = 1.435 Ω

Therefore, P = IV = 8.34 × 11.98 = 99.9 W

Figure 7 shows the operational waveform of the amplifier at an input frequency of 70 Hz given to the amplifier by the frequency generator, yielding an output frequency of 166.6Hz represented as shown in Figure 7.

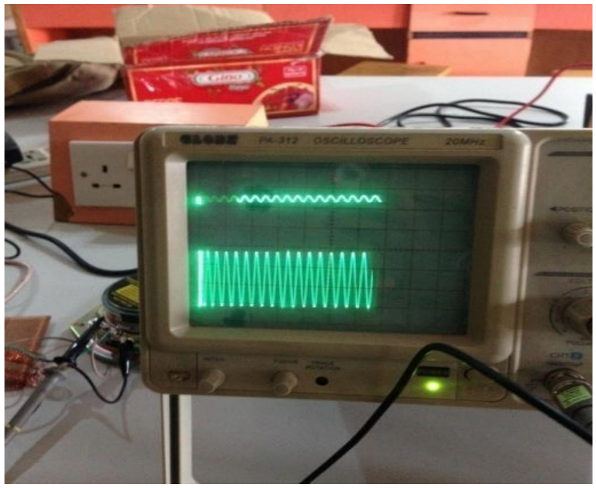

Fig. 7 Signal waveform of the amplifier at an input frequency of 70Hz

The frequency as observed from the waveform shows that; at the input frequency of 70 Hz, t=2 milli sec. This implies that the output frequency is given as $t = 2{\times}10^{-3}{\times}3 = 6{\times}10^{-3}$S.

Therefore, $F = \frac{1}{t} = \frac{1}{6\times10^{-3}}$ (5)

$= \frac{1\times10^{3}}{6} = 166.6$ Hz

It implies that the output signal is twice the input signal, meaning that there is an amplification with the amplifier. That is, the amplifier works is satisfactory.

To obtain the cutoff frequency of the amplifier, given that

$$F = \frac{1}{2\pi RC} \quad (6)$$

Where, R = 1 KΩ = 1000 Ω

C = 1000 μF = 1000×10^{-6} F

Therefore, $F = \frac{1}{2\times3.142\times1000\times1000\times10^{-6}}$

$F = \frac{1}{2\times3.142\times1000\times1\times10^{-3}}$

$F = \frac{1}{6.284}$

F = 0.159 H

4. Conclusion

This study designed and constructed a 100-watt class AB audio power amplifier using a D718 power transistor. The design process was presented in detail and the calculations with respect to the operation and performance of amplifiers were undertaken. In conclusion, the Simulations of the circuit carried out yielded result for the voltage and current: 11.91 V(V_{in}), 5.74 V(V_{out}), 770.43 mA(I_{in}) and 770.43 mA(I_{out}) while the result obtained using multimeter are 11.98 V(V_{in}), 4.34 V(V_{out}), 99.6 mA(I_{in}) and 5.6 mA(I_{out}). The overall power of the amplifier is 99.9 watts, a satisfactory result; thus, the calculated power was 99.9 watts which is cheap, more reliable and more effective to use. Hence, the agreement between the simulated and experimental results confirms the good performance of the amplifier.

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