www.ijemr.net ISSN (ONLINE): 2250-0758, ISSN (PRINT): 2394-6962

Volume-5, Issue-6, December-2015
International Journal of Engineering and Management Research
Page Number: 9-14

Design and Construction of A 300 Watt Audio Amplifier

Oti, S. Ejiofor[1], Ahanonu, C. Silver[2]
Department of Electrical Engineering, University of Nigeria, Nsukka, Enugu State, NIGERIA

ABSTRACT

This paper reports the design and implementation of a 300Watt audio amplifier. The system features also include an LCD. The circuit analysis is presented and procedures for implementation are described. Before implementation, circuit simulation was carried to ensure that simulated results corresponded with the analysis already carried out. Simulation results showed an open-loop gain of about 2600V/V while the result from the amplifier analysis was 2937V/V. This satisfactory results agrees with the required open-loop threshold of >1000V/V for optimal operation. The simulated closed-loop gain was 10V/V which also agreed with design specifications and analysis. The overall result obtained indicates a satisfactory performance.

Keywords--- Audio, Amplifier, Transistor, Gain, *PSPICE.*

I. INTRODUCTION

Amplifiers are electronic devices that boost or strengthen an input signal, in other words, they provide amplification. The nature of the signal could be of any type such as voltage, current or power of a circuit. There are many forms of electronic circuits classed as amplifiers, from operational amplifiers and small signal amplifiers up to large signal and power amplifiers [1]. Amplifiers can be thought of as a simple box or block containing the amplifying device, such as a Transistor, Field Effect Transistor or Operational amplifier (op amp), with the output signal being much greater than that of the input signal as illustrated in figure 1 showing voltage amplification. Therefore, an amplifier's performance can be defined by the quality of its output, it can be said to be high only if the amplified signal contains none or minimum number of distortions or alterations compared with the original input signal.

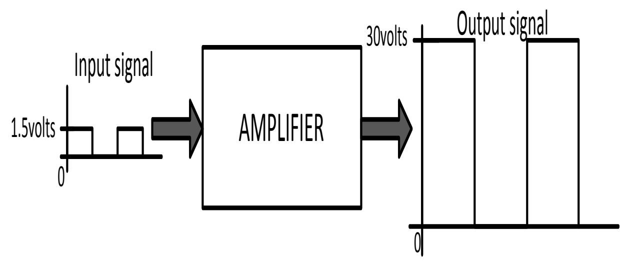

Figure 1. Diagram showing operation of an amplifier

An Amplifier receives a signal from some pickup transducer or other input source and provides a larger version of the signal to some output device or to another amplifier stage. An input transducer signal is generally small (a few millivolts from a cassette or CD input or a few microvolts from an antenna) and needs to be amplified sufficiently to operate an output device (speaker or other power handling device).

The term audio means the range of frequencies which the human ear can hear. The range of human hearing extends from 20 Hz to 20 kHz. Therefore, audio amplifiers amplify electrical signals that have a frequency range corresponding to the range of human hearing, i.e. 20 Hz to 20 kHz, [2] to a level suitable for driving loudspeakers. Early audio amplifiers were based on vacuum tubes (also known as valves), and some of these achieved notably high quality (e.g., the Williamson amplifier of 1947-9). Most modern audio amplifiers are based on solid state devices (transistors such as BJTs, FETs and MOSFETs). Audio amplifiers based on transistors became practical with the wide availability of inexpensive transistors in the late 1960s [3]. This paper reports the design of a 300 watt transistor-based audio amplifier. A practical amplifier always consists of a number of stages that amplify a weak signal until sufficient power is available to operate a loudspeaker or other output device.

1.1 *Practical Audio Power Amplifier*

A practical audio power amplifier must have dedicated circuits for producing voltage gain and current gain. Special emphasis is given to factors like performance, reliability, ruggedness etc, while designing a practical audio power amplifier. Figure 2 shows a simplified three-stage audio power amplifier design.

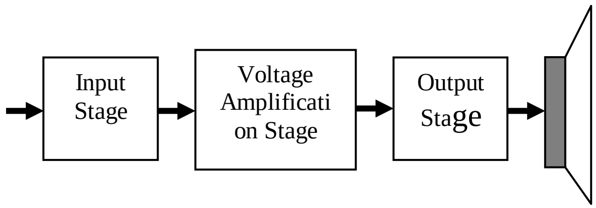

Figure 2. Practical audio power amplifier stages

a. Input Stage

Usually consists of an input differential pair. This stage compares the applied input signal to a fraction of the output of the amplifier and provides the amount of signal necessary for the remainder of the amplifier to create the required output. This operation forms the essence of the negative feedback loop. The fraction of the output to which the input is compared is determined by the voltage divider consisting of R_{F1} and R_{F2}. If the fraction is 1/20 and the forward gain of the amplifier is large, then very little difference need exist between the input and the feed back signal applied to the input stage in order to produce the required output voltage. The gain of the amplifier will then be very nearly 20. This is referred to as the closed-loop gain of the amplifier [4].

b. Voltage Amplification Stage (VAS).

It is a high-gain common-emitter (CE) stage that provides most of the voltage gain of the amplifier. It is not unusual for the VAS to provide a voltage gain of 100 to 10,000. This means that the difference signal needed to drive the input stage does not need to be very large to drive the output to its required level. If the difference signal is close to zero, and 1/20 of the output is compared to the input, it follows that the output would be almost exactly 20 times the input.

c. Output stage.

Output stage is the stage that is connected to the loudspeaker. The output stage is composed of transistors whose main job is to provide buffering in the form of current gain between the output of the voltage amplification stage and the loudspeaker load. Most output stages have a voltage gain of approximately unity. The output stage gives further improvement to the power gain and transfers this power to the loud speaker with minimum loss. Push-pull arrangement consisting of two transistors is often employed in this stage. Efficiency and impedance matching are the two important parameters considered while designing this stage.

II. METHODOLOGY

This section discusses the analysis, design and implementation of the 300W 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 energised. The steps that were taken to design this project includes: (i) Selection of components (ii) Analysis of the amplifier (iii) Simulation of audio amplifier circuit (iv) Design of the printed circuit board (PCB) (v) Circuit construction and testing.

2.1 *Selection of Components for Audio Amplifier Circuit*

The components for the 300W audio amplifier were chosen based on the requirements of the amplifier; the first step is to design a power supply unit for the amplifier circuit. A 300W amplifier would require about ±70V power supply on the rails. This is achieved by coiling a transformer for that purpose using the well-known transformer equation that relates number of turns to voltage and current, expressed below:

$$V_1/V_2 = N_1/N_2 = i_2/i_1$$

The next issue is to proceed to rectify and smoothen the stepped-down AC output of the transformer to achieve a dc output. The bridge configuration of four diodes, 6A each is used for rectification and smoothening is achieved with the use of capacitors. This removes the AC (unwanted) ripples from the DC signal in order to achieve a pure DC voltage fed to the system. Fuses can be added for current protection. Figure 3 shows the power supply circuit.

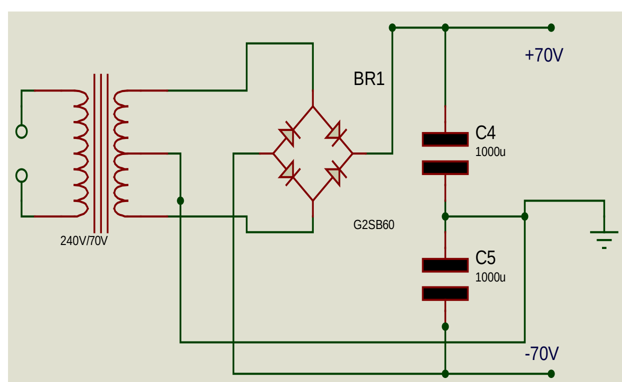

Figure 3. Dual voltage power supply

Next thing is to progress to design the stages in amplifier operation, brief description of the stages in the amplifier is presented below while the analysis of the audio amplifier is discussed in the next section.

A. Input stage

As described earlier, it boosts the input signal coming directly from the source (phone, radio, tv etc)

before it can be further amplified by the power transistors for final output to the speaker.
The pre amplifier stage comprises of 1.5kΩ resistor, BC558 PNP transistors, 10μf/50V capacitor (de-coupling capacitor) for filtration. All these components make up the pre amplifier stage.

B. Voltage Amplification stage

This stage consists of component of class A and component of class B amplifier respectively. It sums up to what is called class AB amplifier. This system is so designed with this combination concept in order to achieve maximum efficiency. The class A amplifier consist of Tip 41 and Tip 142(darlington pair transistor) and class B amplifier consist of Tip 147 power transistor (darlington pair transistor). The combination of these power transistors from both classes result to a PUSH-PULL topology of class AB amplifier.

C. The Feedback stage

In this stage, the output power of the system is compared with the input power from the pre amplifier stage using BC558 PNP transistor and 22kΩ resistor. This system is built to produce a maximum power output of 300W. If this requirement should be violated, the feedback stage will be signaled to and cautious effort would be made by the voltage divider between 22kΩ and 220Ω resistor, else the system will get spoilt.

D. The Output Stage

The output stage consists of 300W rated speaker. The speaker is made up of coil wound round a magnet bar. The PUSH-PULL operation of the power transistor gives the required output result.

2.2 Amplifier Analysis

Figure 4 shows the schematic of the proposed design. Stepping through the proposed audio amplifier with a signal gain of 10 V/V (20 dB). It is run from a +/- 70V supply.

A. DC BIAS

Firstly, we calculate the bias current of Q_1 and Q_2. The current through R_E splits into Q_1 and Q_2, so we calculate

$$i_{c1} = i_{c2} = \frac{1}{2} I_{bias}$$

where I_{bias} is total bias current given by

$$I_{bias} = \left(V_{cc} - V_{beQ_1}\right)/R_E$$

where V_{cc} is the supply rail of +15V and V_{be} is the base-emitter voltage of transistor Q_1. Therefore:

$$i_{c1} = i_{c2} = \frac{1}{2}(15 - 0.7)/14.3k = 0.5mA$$

Initially, set R_{C1} to 0.7V/0.5mA = 1.4k to get I_{c1} = 0.5 mA. But R_{C1} needs to be adjusted until $I_{c1} = I_{c2}$ approximately. From the simulation, this results in R_{C1}=1.5k.
Q_3's collector current is calculated as

$$i_{c3} = \left(V_{cc} - V_{beQ_4}\right)/R_{C3} = (15 - 0.7)/4k = 3.6mA$$

B. AC SMALL-SIGNAL GAIN

The transconductance g_{m1} of Q_1 is obtained as follows:

$$g_{m1} = i_{c1}/V_T = 0.5mA/26mV = 0.0192(A/V)$$

The current output of the differential input stage is

$$i_{c1} = v_{in}\left(\frac{1}{2}\right)g_{m1}$$

resulting in

$$i_{c1} = v_{in}\left(\frac{1}{2}\right)0.0192 = v_{in}(0.0096)(A/V)$$

with β_3 = 100, Q_3's input resistance becomes

$$r_{in3} = \beta/(i_{c3}/V_T) = 100/(3.6mA/26mV) = 727\Omega$$

Collector current i_{c1} will split between R_{C1} and *rin3*, defined by

$$K_i = i_{b3}/i_{Ci} = R_{C1}/(R_{C1} + r_{in3}) = 1.8k/(1.8k + 727) = 0.712$$

Q_3 converts Q_1's output to voltage by $\beta_3 \times R_{C3}$. The overall open-loop gain becomes

$$A_{ol} = v_{c3}/v_{in} = \frac{1}{2} g_{m1}(K_i)(\beta_3)(R_{C3}) = 2739(V/V)$$

With large open loop gain A_{ol}, we can close the loop with R_{F1} and R_{F2} setting the closed-loop gain as

$$A_{cl} = v_o/v_{in+} = R_{F1}/R_{F2} + 1 = 100k/11k + 1 = 10(V/V)$$

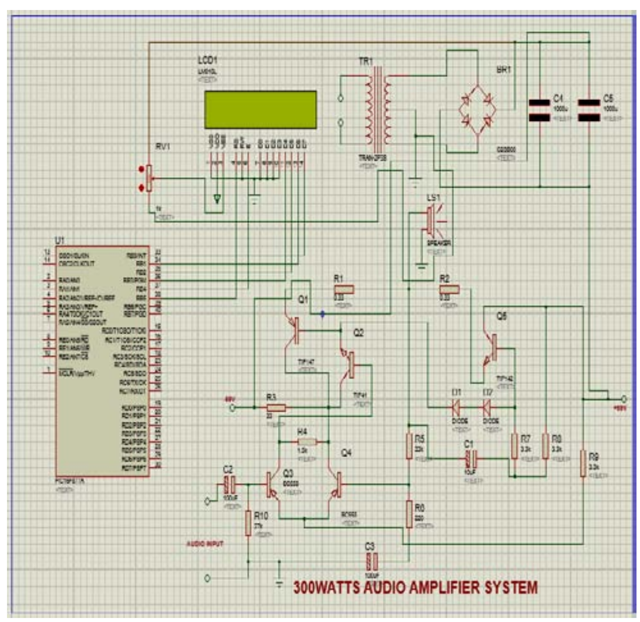

Figure 4. Model of audio amplifier including the LCD (5)

2.3 Simulation and construction and testing

Simulation of audio amplifier circuit was carried out using Proteus 8 Professional® software. Observations from the simulated outputted signals were used to determine the theoretical and calculated result. The calculated results were similar to simulated results and the system was designed based on the simulated circuit. The circuit simulated is shown in Figure 4. The audio amplifier system is also equipped with an LCD display that shows the name and registration number of the authors. This was also incorporated in the circuit model and implementation. The LCD is controlled from a PIC microcontroller. The program code for the microcontroller is presented in the appendix. ARES, a part of Proteus software, was used to design the printed circuit board. The circuit was printed using a laser jet Printer on "glossy paper". This paper is used because it can release the laser on the surface when heated at a certain temperature. The next step is the heating of the glossy paper. The glossy paper is placed on the surface of a copper chloride board and an electric iron was used to heat the glossy paper for some minutes. After that, the board was placed into a bowl of water for cooling and unwrapping (peeling off).

The board was placed into a bowel of ferric chloride for etching. The copper which were not photo-resisted are etched. The next process is to remove the lasers on the copper surface. These lasers are removed by cleaning with thinner obtained from local stores, it is also used to remove point stains from materials. Holes were drilled into the PCB using 1mm drilling bits, for placement of component parts. The circuit was soldered properly to the board and air gaps were prevented.

The constructed circuit was tested by plugging it to the AC mains (220V/50Hz). The audio input was connected to a GSM phone and the output signal was attenuated due to noise. The noise was introduced due to faulty volume tuner, which was replaced and a better output signal was obtained. In other to improve the output signal, the system had to undergo several optimization processes such as filtration using capacitors with satisfactory results. The circuit board implementation is shown in Figure 5.

Figure 5. Circuit board implementation of audio amplifier

III. RESULTS AND DISCUSSION

A. Open Loop A_{ol} Gain

Figure 6 shows the open loop gain of the amplifier, which is a ratio of the output voltage to the input voltage without the feedback resistors. From the analysis made in section 2.2, the calculated open loop was 2739V/V, simulation results show the open loop gain to be about 2600V/V. A gain of >1000 is required if we expect the amplifier to have an accurate signal gain (+10 in this case) and low distortion when the loop is closed. With satisfactorily large open-loop gain, then very little difference need exist between the input and the feedback signal applied to the input stage in order to produce the required output voltage.

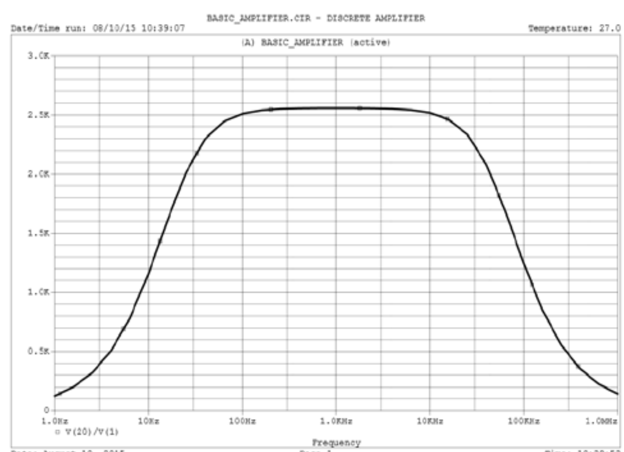

Figure 6 Simulated open loop gain A_{ol} of proposed amplifier

B. Closed-loop Gain A_{cl}

Figure 7 shows the simulation output of the amplifier in closed loop with the feedback resistors connected. Our calculated closed loop gain A_{cl} was 10V/V

 ISSN (ONLINE): 2250-0758, ISSN (PRINT): 2394-6962

and this agrees with simulation results just as the circuit satisfactorily functions as an amplifier.

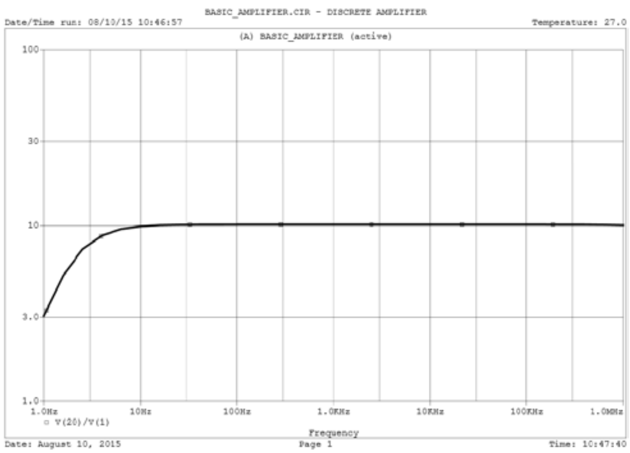

Figure 7. Closed loop gain A_{cl} of the proposed amplifier

C. Amplifier Operation

Figure 8 shows the operation of the amplifier. Voltage source V_S generates a 0.1 V peak sine wave at 1 kHz. The input and output signals are plotted after simulation. There is an output of approximately 0.1V x 10 = 1.0 V. Functioning properly as an amplifier with a gain of 10.

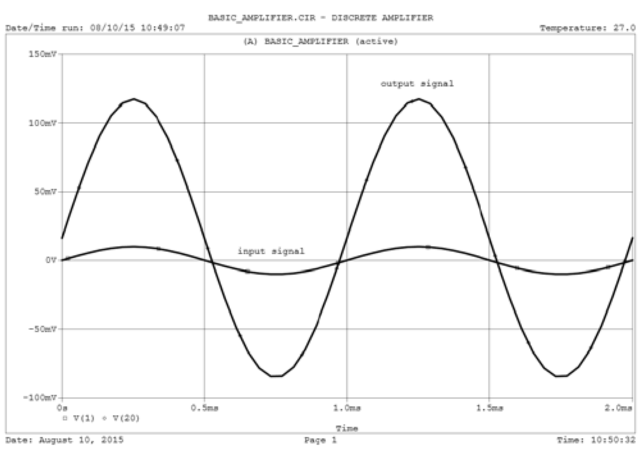

Figure 8. Circuit in operation as an amplifier

D. Balance and Total Harmonic Distortion

Figures 9 and 10 show the balance in the signals from the transistors Q1 and Q2 at the differential input stage. Figure 9 shows that the two transistors are matched and Figure 10 shows the Fourier representation of figure 9, with near zero distortion. Appended in Table 1 is the summary of simulation results using PSPICE showing the total harmonic distortion of the simulation results to be less than 1%, 0.3% actually.

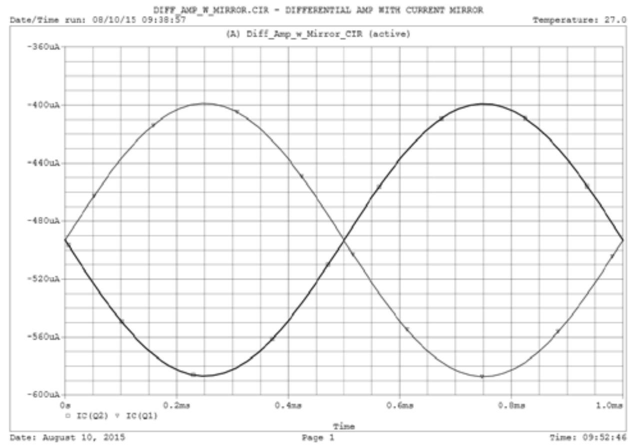

Figure 9. Signal balance of transistors Q_1 and Q_2 at the differential input stage.

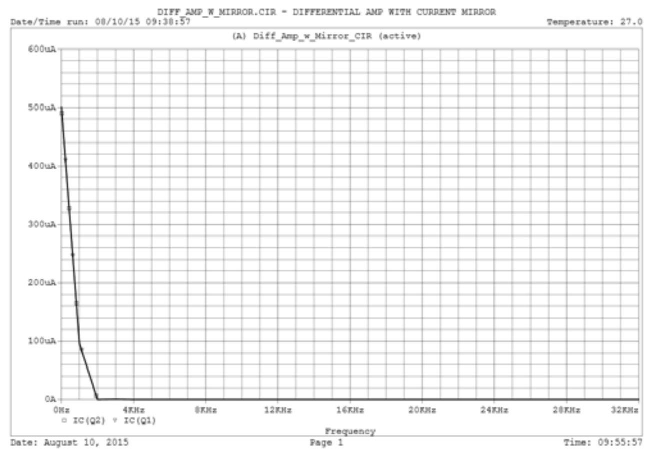

Figure 10. Total harmonic distortion

Table 1 Total harmonic distortion computation from simulation

DIFF_AMP_W_MIRROR.CIR - DIFFERENTIAL AMP WITH CURRENT MIRROR
FOURIER ANALYSIS TEMPERATURE = 27.000 DEG C
FOURIER COMPONENTS OF TRANSIENT RESPONSE V(7)
DC COMPONENT = -1.433941E+01

HARMONIC NO	FREQUENCY (HZ)	FOURIER COMPONENT	NORMALIZED COMPONENT	PHASE (DEG)	NORMALIZED PHASE (DEG)
1	1.000E+03	1.868E-01	1.000E+00	-8.780E-04	0.000E+00
2	2.000E+03	3.286E-05	1.759E-04	1.215E+02	1.215E+02
3	3.000E+03	5.725E-04	3.065E-03	2.719E-01	2.745E-01
4	4.000E+03	1.417E-06	7.585E-06	-1.450E+02	-1.450E+02


```
    5    5.000E+03   3.156E-06   1.690E-05   2.698E+01
2.698E+01
    6    6.000E+03   2.783E-07   1.490E-06  -2.273E+01
-2.272E+01
    7    7.000E+03   8.545E-07   4.574E-06   6.799E+01
6.800E+01
    8    8.000E+03   6.075E-07   3.252E-06   9.867E+00
9.874E+00
    9    9.000E+03   6.004E-07   3.214E-06   5.033E+01
5.034E+01

    TOTAL HARMONIC DISTORTION =   3.069842E-01
PERCENT
        JOB CONCLUDED
        TOTAL JOB TIME            .13
```

IV. CONCLUSIONS

The design and implementation of a 300Watt audio amplifier has been reported. The design process was presented in details and the calculations with respect to the operation and performance of amplifiers were undertaken. In conclusion, the simulations carried out supported the calculations. This had to be ensured before the actual implementation of the design. The open and closed-loop gains, were presented in the results sections and an open loop gain >1000 and a closed loop gain of +10V/V were achieved. Total harmonic distortion in the system was also less than 1%.

REFERENCES

[1] Lakshanhere Hubpages, "How to design an Amplifier using given Gain, Input Impedance and output Impedance.,”. Available:http://lakshanhere.hubpages.com/hub/How-to-design-a-Amplifier-using-given-Gain-Input-Imphedance-and-output-imphedance. [Accessed 26 June 2015].
[2] V. Mehta, Principles of Electronics, New Delhi: S. Chand, 2008.
[3] Wikipedia, "Audio Power Amplifier," Available:https://en.m.wikipedia.org/wiki/ Audio_power_amplifier. [Accessed 8 August 2015].
[4] B. Cordell, Designing Audio Power Amplifiers, New York: McGraw Hill, 2011.