DESIGN AND CONSTRUCTION OF AUDIO POWER AMPLIFIER

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Abstract: *Amplifiers, as the name implies, are electronic devices that boost or strengthen an input signal. This study designed and constructed 30 W audio power amplifier using TDA2040 modules from the circuit digest. The amplifier was designed and constructed using integrated Circuit (TDA2040) and the simulation of the circuit was carried out using proteous 8 professional. The power supply unit was constructed using 12V-0-12V center-tap step-down transformer and thereafter the amplifier. The amplifier was tested and the results showed that the amplifier exhibited low distortion. The output power and efficiency were found to be 30.00 watts and 78.5 % respectively. The circuit simulation was a success, and that the agreement between the simulated and experimental result confirms the good performance of the amplifier.*

Keywords*: Audio, Power, Amplifier, Vero board, Ripples, Signal*.

Introduction / Background Study

An audio power amplifier is also referred to as power amplifier. It is an electronic device that amplifies low-power electronic audio signals such as signal from radio receiver or electric guitar pick up to a level that is high enough for driving loudspeakers or headphones (Rahman & Razzak, 2012). Amplifiers, as the name implies, are electronic devices that boost or strengthen an input signal. Amplification is defined as the process of increasing the size (magnitude) of a variable quantity especially the magnitude of a voltage or current, without substantially changing or altering any other quality (Oliveira *et al.*, 2000). The nature of the signal could be of any type such as voltage, current or power of a circuit (Oti & Ahanonu, 2015). The first practical device that could amplify was the triode vacuum tube, invented in 1906 by Lee De Forest (who is regarded as the father of amplifier) (Gupta, 2018). The triode was a three-terminal device with a control grid that can modulate the flow of electrons from the filament to the plate. The triode vacuum amplifier was used to make the first AM radio. Early audio amplifiers were based on vacuum tubes otherwise known as valves (Rahman & Razzak, 2012). These vacuum tubes were used in almost all amplifiers until around 1960 to 1967 when transistors replaced them. Today, most amplifiers used transistors with chips (IC) but vacuum tubes are being used in some applications (Cordell, 2011). 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 wide availability of cheap transistors in the late 1960s (Ben, 2000). 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 devices. The few stages in a multistage amplifier have the function of only voltage amplification; however, the last stage is designed to provide maximum power and this final stage is known as power stage. The term 'audio' means the range of frequencies which human ears can hear. The range of human hearing extends from 20 KHz to 200KHz. For this reason, audio amplifiers amplify electrical signals that have a frequency range corresponding to the range of human hearing range to a level suitable for driving loudspeakers (Mehta, 2008). Audio power amplifier are classified primarily by the design of the output stage and the classification is based on the amount of time the output devices operate during the cycle of signal swing (Gupta, 2018).

Methodology

The design uses a dual class AB amplifier known as TDA2040. The IC was built in a way that it does the amplification itself and has five (5) pins which are attached to capacitors and resistors (for filtering, smoothening and frequency stability). The IC class AB amplifier was chosen because of its low distortion, high efficiency, availability, easy to implement and low power loss.
The construction of the amplifier was based on the circuit simulation. First, the power supply unit was constructed based on the specification of the proposed amplifier. A 25watt amplifier would require about $\pm$17 V power supply on rail (Eq. 1).

$$V_{ref} = V_{rms} \times \sqrt{2} \sim 16.9\text{v} \ (V_{rms} = 12\text{v}). \quad (1)$$

The next was 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 1A each were used for rectification and smoothening was achieved with the used of two capacitors each of 330µf. This removes the AC unwanted ripples from the DC signal in order to achieve a pure DC voltage fed to the system. A blue print of the amplifier was first drawn on paper and later used as a guide to solder all the components on the Vero board. Air gap were avoided as much as possible while soldering the variously components. The following formulae were used in estimation:

Wattage power= V^2/R, (2)
where: V and R being voltage gain and resistance respectively.

Efficiency $^{P_{0\ (ac)}}/_{P_{i\ (dc)}}$ X 100%, (3)

where: $P_{0\ (ac)} = {}^{V\ cc^2}/_{2R}$ &$P_{i\ (dc)} = {}^{2\ V\ cc^2}/_{\pi R}$

Gain of the amplifier = $^{R_2}/_{R_3}$ (4)

Amplifying factor, $A_f = {}^{R_2}/_{R_3} + 1$ (5)

Design specifications
The design of the audio power amplifier was based on TDA2040 and according to the ST. Microelectronics data sheet (2012), the TDA 2040 has the following features:

i. Wide range supply voltage, up to 40V.
ii. Single or split power supply
iii. Short-circuit protection to ground
iv. Thermal shutdown
v. P_O=25W @THD= 0.5%, V_S= ±17 V, R_L=4Ω
vi. P_O=30W @THD= 10%, V_S= ±17 V, R_L=4Ω

The TDA2040 is a monolithic integrated circuit in the Penta watt package, intended for use as an audio class AB amplifier. Typically, it provides 25W output power into 4Ω with THD of 0.5% at supply voltage of 34V. The TDA2040 provides high output current and has very low harmonic and cross over distortion. More so, the device incorporates a patented short-circuit protection system.

The Power Supply Unit
The audio power amplifier shall be using dual rail power supply. Hence, this unit shall use a step-transformer of the rated voltage having a center tap output or secondary. The secondary side shall be using a bridge rectifier and smoothening capacitors. The configuration takes the dual rail power supply and uses two capacitors as shown in the circuit diagram.

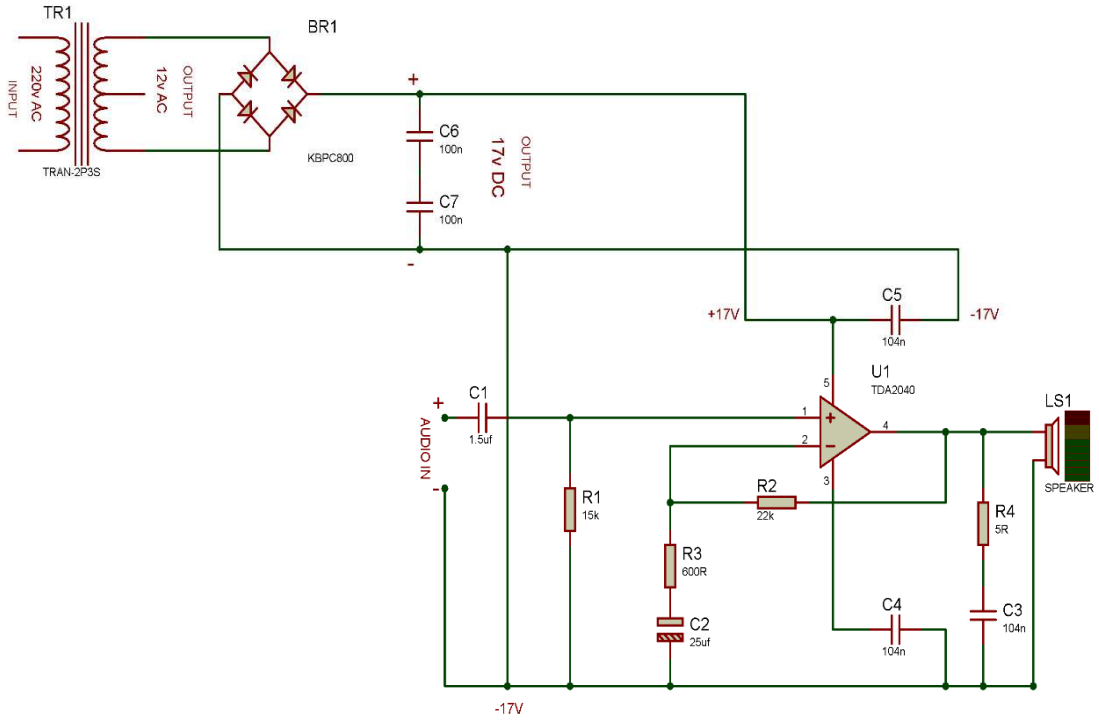

Figure 1: The circuit diagram with the power supply unit

Circuit Operation
The TDA2040 is amplifying the signal and providing 25W rms wattage to the 4Ω loudspeaker. The C4 and C5 are used as decoupling filter capacitor while C1 and R1 are acting as filter. R2, R3 and C2 are providing the necessary feedback to the power amplifier and finally the R4 and C3 are the snubber circuit to clamp the feedback from the inductive load (loud speaker) as shown in the circuit diagram.

Simulation
The simulation of audio amplifier circuit was carried out using proteus 8 professional software. The simulated circuit consists of resistors and capacitors for filtering, smoothening and frequency stability.

Casing
After a satisfactory result was obtained, the various sections (the power supply unit and the amplifier) were assembled and put inside the wooden case. Prior to the making of the casing, measurements of the sizes desired were taken into consideration with black plastic rubber as the front and metallic plates as the top and back cover whereas the base and sides cover were made up of wood. The front cover bears the power switch, volume controller, pilot LED and phone input jack. The back-cover features fuse switch for power supply and speaker output terminals. Thus, the power supply unit and the amplifier are put under the same casing while the speaker was cased separately.

Results and Discussion

Measurement of the Voltage Using Oscilloscope
The Simulated Circuit is shown in Fig. 2. The oscilloscope was first calibrated by connecting the probe to the input at Y terminal and the other terminal was used to touch the hole meant for calibration and a sine wave was seen on the oscilloscope screen, indicating its readiness for use. But where a sine wave is not seen or shown on the screen, then it is adjusted using the vertical and horizontal adjustment knob alongside the variable until a sine wave is obtained or else the oscilloscope cannot be used. After the calibration of the oscilloscope, then an audio signal (sound source) from a phone with a frequency set at 1KHz (as required by the oscilloscope) is then connected to the phone using RCA jack cable and then the probe (with two terminals) is connected to the other end of the RCA jack code that comes from the phone and the sine wave is shown on the oscilloscope's screen (Fig. 3).

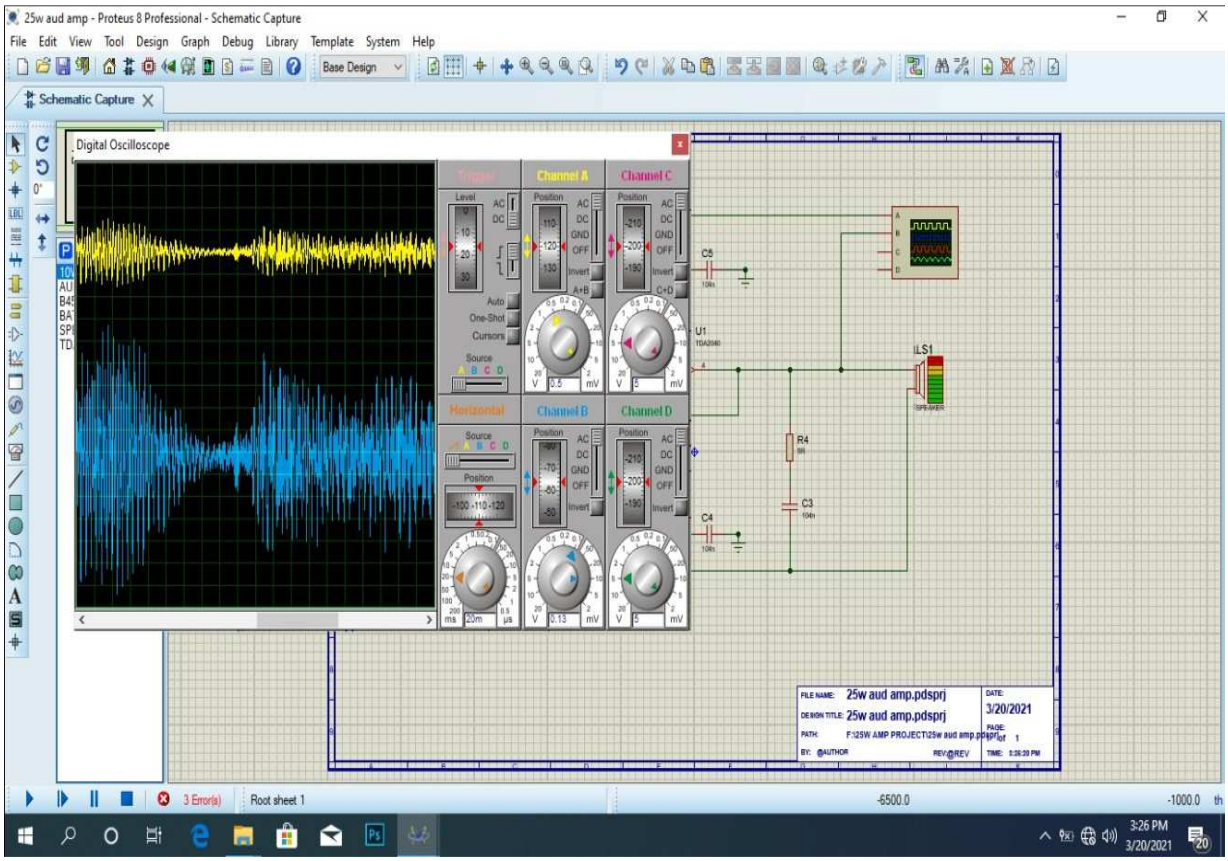

Figure 2: The Simulated Circuit

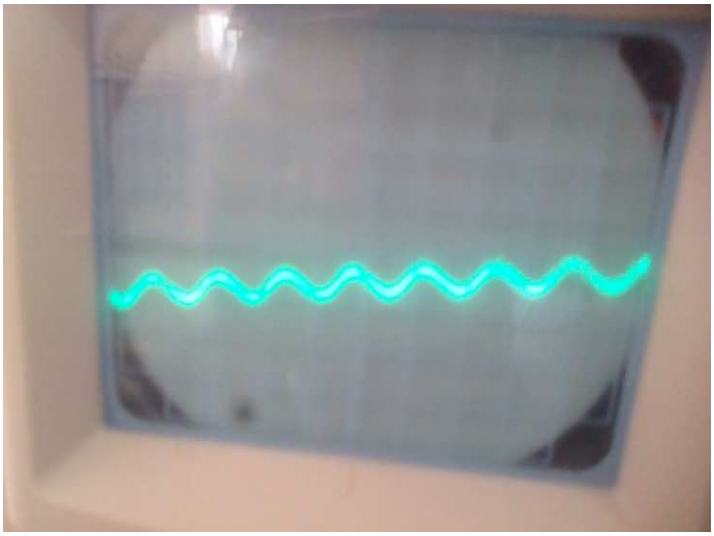

Figure 3: Input Voltage Waveforms

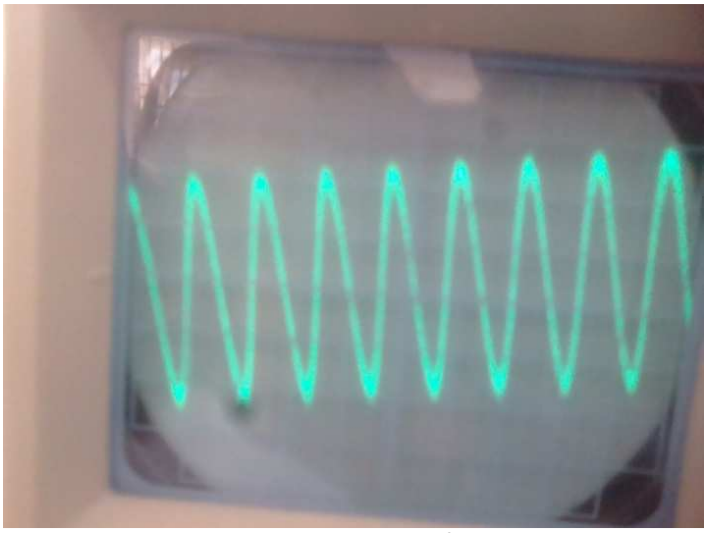

Figure 4: Output Voltage Wave forms

The scale used was earlier set at 0.2V and then the peak-peak voltage was measured.
V_{p-p} =$\frac{1}{2}$ x 2 x 0.2 = 1 x 0.2 = 0.2V.

Input Voltage, $V_1 = 0.2V$.
For the V_2, the same thing was done only that the sound source from the phone was then introduced to the amplifier via RCA jack and the amplifier was set at highest volume. The probe was connected at the output of the amplifier, that is, from the wires that go to the speaker. The sine wave is as well shown below in Fig. 4.

The peak voltage is, V_{p-p} =1 x 4.5 x 0.5 = 2.25V.
Output voltage, V_2 = 2.25V.

Figure 5: The Constructed Audio Power Amplifier

Figure 2 shown above is the simulated circuit. Prior to the construction of the amplifier, the simulation of the circuit was carried out using proteus (8) professional software. Observations from the simulated output signals were taken into cognizance, hence the simulation was a success and the systems were constructed based on the simulated circuit. It equally shows the input voltage waveform before the amplification and simultaneously the amplified voltage waveform. The input is connected to channel A while the output is to channel B as shown above. Figures 3 and 4 are the input and output voltage waveforms measured from the constructed amplifier using cathode ray oscilloscope as the pictures has it. Figure 5 shown above is the constructed amplifier. 30W of power was obtained as the amplifier's output power.

Numerical Results

i. Wattage power, $P_0 = {V^2}/{R}$, where V and R being voltage and resistance respectively. V is the voltage gain = ${V_2}/{V_1} = {2.25}/{0.50}$, V= 11.25v and R=4Ω. ∴ P_0 = 30.25 W

ii. Efficiency of a system is defined as the ratio of the useful delivered power output divided by the input power
Efficiency = ${P_{0\ (ac)}}/{P_{i\ (dc)}}$ X 100%,

where $P_{0\ (ac)} = {V\ cc^2}/{2R} = {12^2}/{2X4} = 18$

$P_{i\ (dc)} = {2\ V\ cc^2}/{\pi R} = {2\ X12^2}/{3.142X4} = 22.92$

∴Efficiency= 78.5%

iii. Gain of the amplifier = ${R_2}/{R_3} = {22{,}000}/{600}$ = 36.67

iv. Amplifying factor, $A_f = {R_2}/{R_3} + 1$ = 37.67

Table 1: Results of the Amplifier

S/N	Parameters measured	Values obtained with unit
1.	Amplifier Wattage	30.00 W
2.	Voltage Gain	11.25 V
3.	Amplifier Gain	36.67
4.	Amplifying Factor	37.67
5.	Efficiency	78.5 %

Results of the Amplifier are shown in Table 1. The audio power amplifier designed, constructed and demonstrated using the TDA2040 showed a satisfactory result. The amplifier is capable of driving 30.00 watts of power into a 4-ohm speaker when a voltage supply of ±17V is used. The amplifier's efficiency is found to be 78.5% though the amplifier is believed to have a distortion of 10%, which is still very low and very low noise level. The designed and developed public address audio amplifier reveals the input and output power to be 42 watts and 30.00 watts while the efficiency was 78.5 % which showed that the developed amplifier worked satisfactorily. This result is in conformity with the results of Rahman & Razzak (2012) who designed and developed audio power amplifier but using a different IC and LM1875. The amplifier was only able to deliver 25 W using an 8-ohm load and dual 30V DC power supply with same efficiency (78.5 %). The same is the case with Ben (2000) who designed and constructed a stereo amplifier and found the chosen design performing almost perfectly to specifications with distortion when simulated in the Microsim PSPICE^{TM} circuit simulator but under actual construction there was higher amplification. The circuit was an overall success but things did not work out as originally planned. Additionally, the experimentation with power amplifier resulted in the destruction of many NPN and PNP BJT's. Finally, the results obtained from the simulation and the designed amplifier were in agreement with each other. 30.00 watts was found to be capable of driving a 4-ohm load (speaker) using TDA2040 on a dual rail of ±17 V. The efficiency, gain and amplifying factor were 78.5 %, 36.67 and 37.67 respectively which confirms the reliability of the amplifier.

Conclusion

Audio power amplifier was based on TDA2040 module from the Circuit digest. It was able to deliver up 30.00 W of power using 4ohm load and dual 17V DC power supplies. It was designed to operate with minimum external components with current limit and thermal shut-down protection features. Before the implementation, simulation of the circuit was carried out. The overall performance of the amplifier was quite good as exhibited by the gain and the amplification factor of the amplifier which were 36.00 and 37.67 respectively.The simulation program was successfully achieved which supported the real constructed amplifier.

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