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Design and Construction of 100Watts Powered Woofer

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Abstract

This study investigates the design and construction of 100 watts powered woofer. This consists of a pre-amplifier, a power amplifier and a light display unit, making use of an IC (integrated circuit)-TDA 7294. The amplifier operates in class AB mode and attains an output power of 100W into 8Ω load, which gives the amplifier an efficiency of 71.43%. The frequency response range (Band width) is 40Hz – 3 KH.

Key words: Amplifier, power, frequency.

1.0 Introduction

A Powered Woofer is an amplifier which has its own built in amplifier. It is basically a low pass filter which has a better response to low frequency audio signals. An audio power amplifier is designed to operate in the audio range of frequencies that extends from 20Hz to 20 kHz [1]. A power amplifier is an amplifier with a power gain. It is usually used so that the output is not applied to the input of a further amplifier state, but to an output transducer such as an aerial or loudspeakers. The amplifier increases the magnitude of an input signal, which may be coming from a microphone, record player e.tc [2].

In all electronic equipment e.g. Radios, television etc, the input signal originates from either speech sound or visual images. These are then converted into electrical signals for the purpose of amplification or for the purpose of transmission over a long distance before being converted back to its original form for reception [3].The device used for converting energy from one form to another is called a transducer. A microphone is a transducer which converts sound pressure to an electrical current that is representative of the amplitude and frequency of the applied sound pressure. However the current is not strong enough to drive a loudspeaker. An amplifier is therefore needed or connected between the microphone and the speaker in order to increase the amplitude of the current. Thus, amplifier are basically needed to increase the amplitude of a transducers output. The electrical signal produced by most transducers usually quite small of the order of 0.1V to 0.0000001 V. For this signal to be useful in say driving a loudspeaker or turning on an indicator light, its amplitude must be increased [3]. Most present day amplifiers requires an external speaker to function which most a times uses a full range speaker, while the home theater system which has a powered woofer (self-powered speaker) is expensive and replacement of component(s) is difficult due to unavailability of some of the components. Hence, a need to design and construct a powered woofer whose components are readily available and cheap within our society. Which will enhance; Increase in audible level of speech of individual in large congregation, camp, meetings e.t.c, Production of high fidelity sound in home audio system which is cheap and readily affordable. This research is carried out via steps or methods used in designing, constructing and results analysis of the pre-amplifier stage, power amplifier stage, and light display unit.

2.0 Materials and Method (Experimental Work)

The 100 watts powered woofer consists of one channel made up of a Pre-amplifier, Power amplifier and light display stage This is represented with the block diagram in Figure 1.

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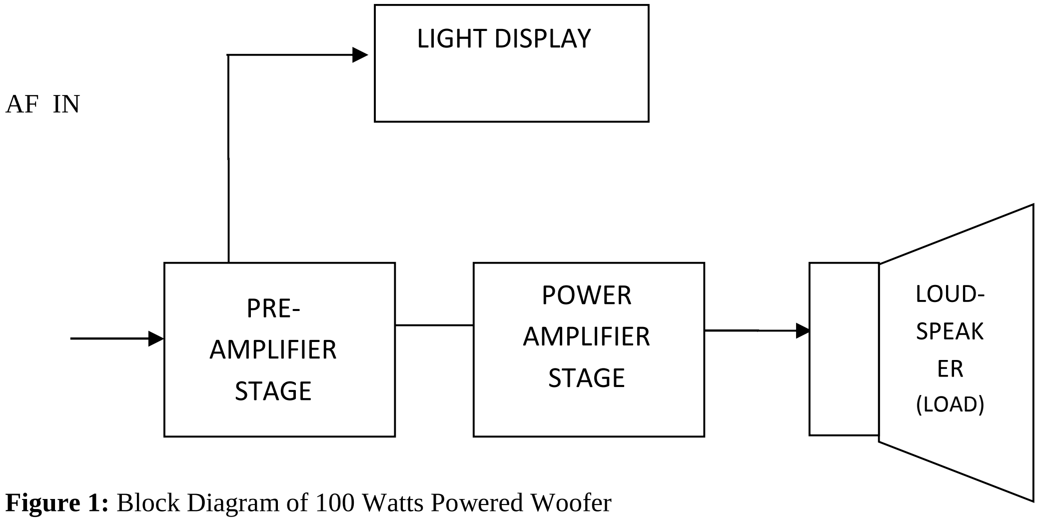

Figure 1: Block Diagram of 100 Watts Powered Woofer

From Figure 1, the pre-amplifier makes use of 741 operational amplifier because of the following reasons: It has guaranteed low noise, It has internal frequency compensator, It is short circuit protected, it is a general purpose integrated circuit and it is a class A amplifier. The pre-amp is chosen to work with sources of strong signals.TDA 7294 is chosen for the power amplifier stage due to the following reasons: It has very high operating voltage range (±20V to ± 40V), Dmos power stage, High output of up to 100w music power, Muting/stand-by functions, No switch on /off noise, Very low distortion, Very low noise, Short circuit protection and overload protection, Thermal shut down while the light display unit makes use of two ICs namely IC1(NE 555) and IC2 (CD 4017). The following symbols and others that were specified are used in the design: AF=Audio frequency, D= Diode, T= Transformer, VR_1=Variable resistor (volume control), A_F=Amplification factor, C=Capacitance, A_{vcl} = Average close loop voltage, A = Open loop voltage gain, F=Fuse and R=Resistance. The circuit diagram of the Preamplifier is shown in Figure 2.

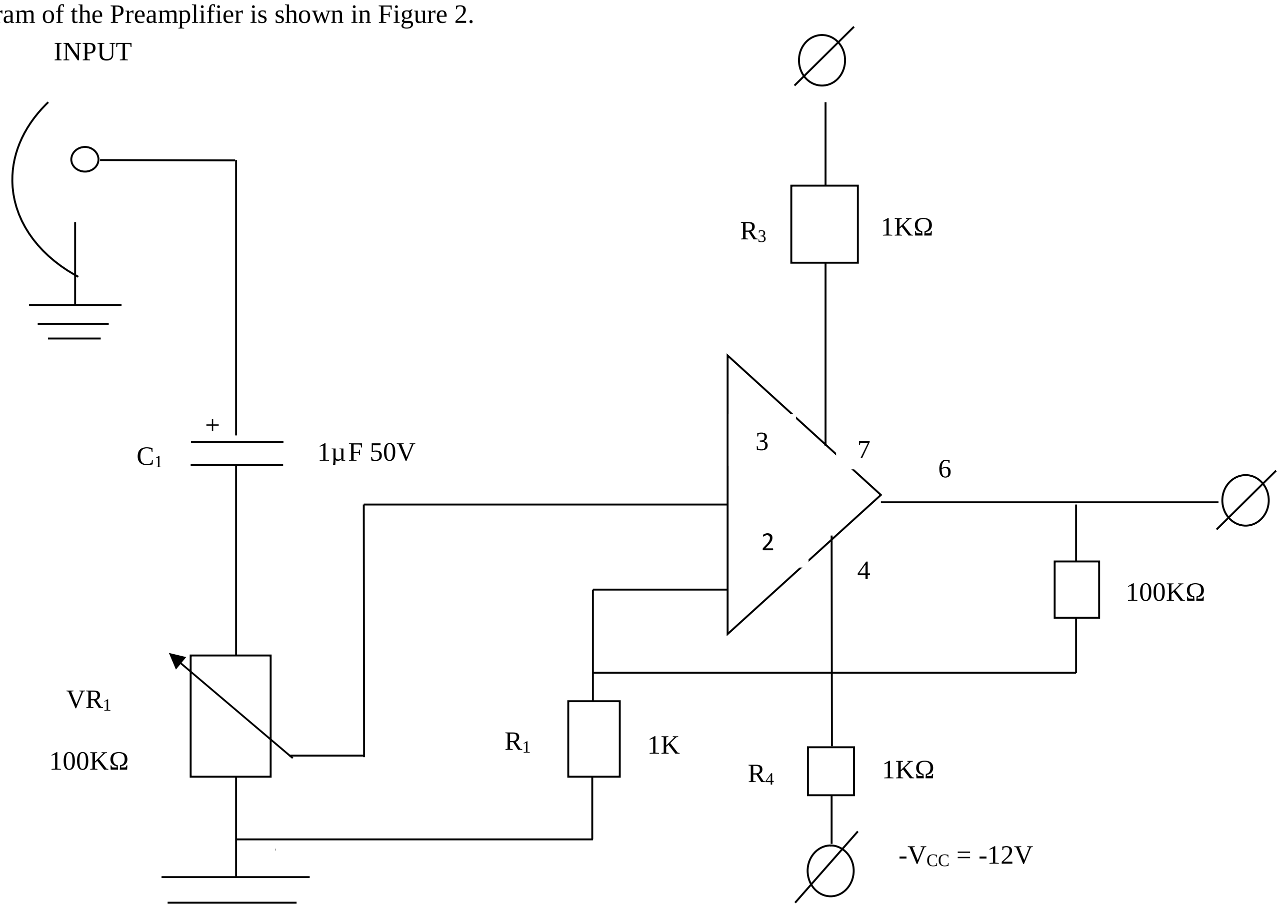

Figure 2: Pre- Amplifier Stage

For the Preamplifier circuit shown in Figure 2,Average close loop voltage (A_{vcl}) across VR_1 was chosen in the range of 1mv to 10mV while input bias current in the 741 operational amplifier was chosen as 100nA. From Ohm's law

$$V\ _1 m = \frac{1m}{1\ \ n} = 10k \quad \text{While } V\ _1 m = \frac{1\ \ m}{1\ \ n} = 100k \qquad (1)$$

The VR_1 will operate in the range of 10KΩ to 100KΩ hence a preferred value 100 KΩ variable resistor was made. For minimum input offset VR_1 was made equal to R_2. This condition ensures that both currents have the same resistance to the ground [4]. The open loop voltage gain of 741 IC is 100dB, It follows that:

$$A = \frac{R_1+R_2}{R_1} \qquad (2)$$

Substituting Av as 100 and R_2=100kΩ gives R_1 as 1kΩ such that the amplification factor becomes, $A_f = \frac{R_1}{R_1+R_2} = 0.01$ (3)

The amplifier input resistance R_{IN} is given by:

$$R_3 = \frac{R_1R_2}{R_1+R_2} = 1k \qquad (4)$$

R_3 was made equal to R_4 for maximum supply voltage. This condition enables pin 7 to be connected to the positive terminal while pin 4 is connected to the negative terminal [5].

Assuming a choice of 1.5 Hz frequency with R_3been $1k$, the input capacitance required is

$$C_1 = \frac{1}{2\pi R_3 F} = 1\mu F \qquad (5)$$

The preamplifier power supply circuit diagram is shown in Figure 3

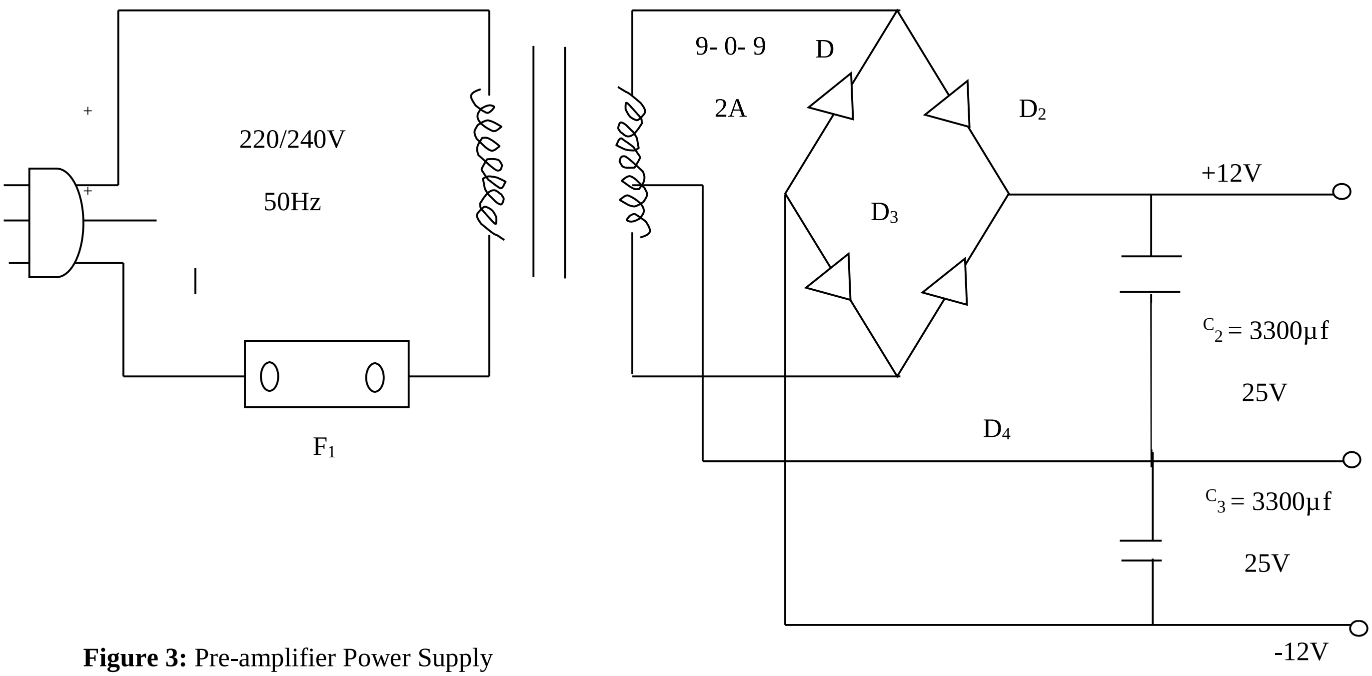

Figure 3: Pre-amplifier Power Supply

For the Preamplifier power supply design, The 741 op-amp operates within the voltage range of ± 4.5v to ±18v. Assuming a choice of ± 12v which is ideal for the operation of the circuit[6].A choice of 9v- 0- 9v , 2A Direct current step down transformer was made which according to root mean square relation gives a peak DC output of $\sqrt{2} \times 9v$=12.73v. But for a requirement of 12V, a difference of 0.73V is negligible due to variations in Alternating Current supply per time [7]. Using V=12.73, F=50Hz and I=2A, the filter capacitor, $C_2 = C_3$is expressed as:

$$C = \frac{Q(T\ )}{V} = 3142\mu F \qquad (6)$$

For implementation, a standard value of 3300 µF, 25V is preferred. Since the supply is dual. Two of the capacitors were used (i.e. $C_2 = C_3$ = 3300µF, 25V). A fuse of I= 1.0A rating was used

Applying Ohm's law and assuming Load resistor R_L = 8Ω while IN4001(4 diodes) rectifier diodes was used.

The circuit diagram of the Power Amplifier is shown in Figure 4.

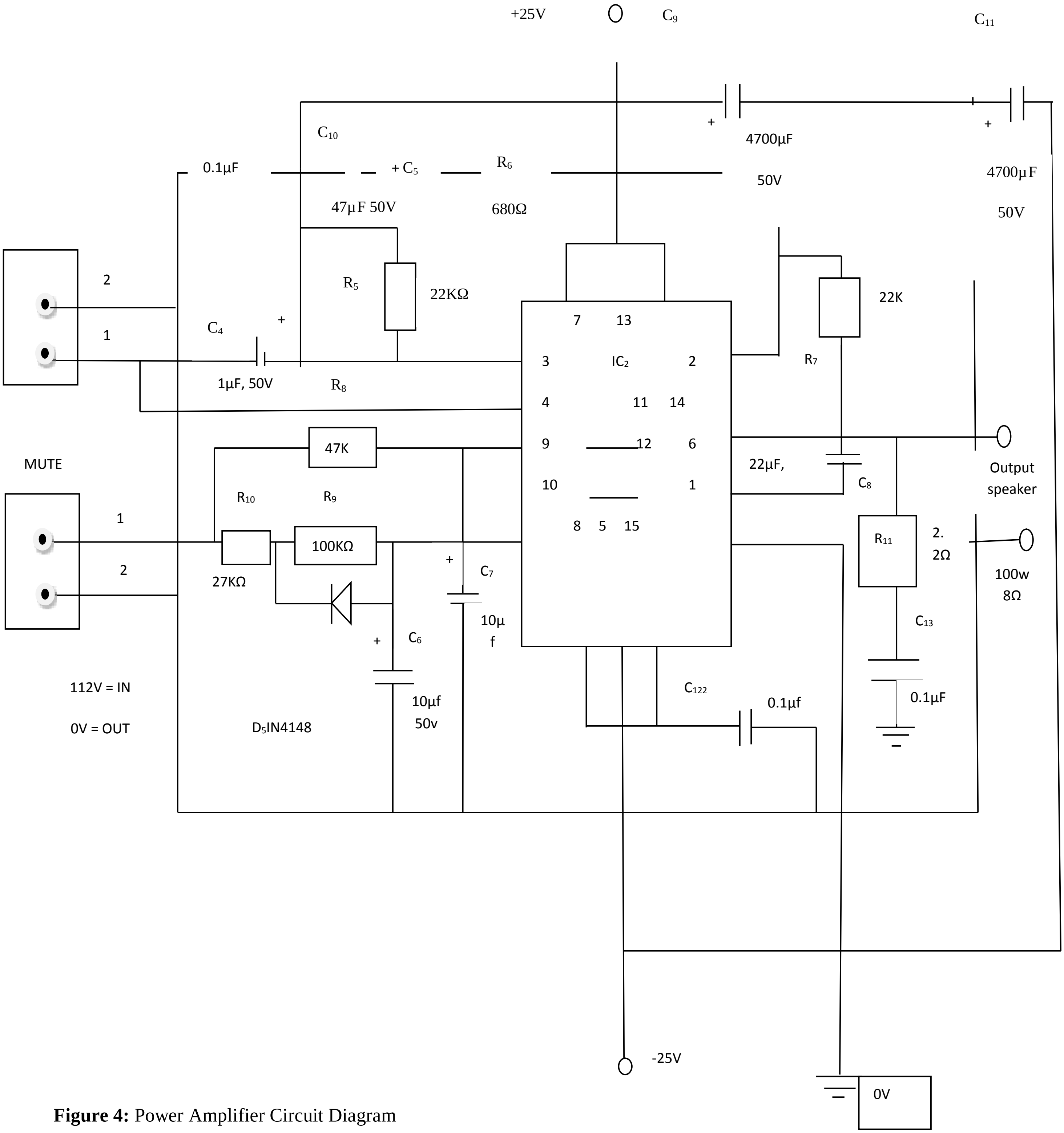

Figure 4: Power Amplifier Circuit Diagram

For the Power amplifier in Figure 4, a choice of input voltage of 10mV and Input bias current of 500nA was made. From Ohm's law,Input resistance
$R_5 = 10 \times 10^{-3} x500 \times 10^{-9} = 20K\Omega$. (7)

For minimum offset, input resistance is made equal to the feedback resistance i.e. $R_5 = R_7$, but for implementation, $R_5 = R_7$ is chosen as 22k which ensures that both currents have the same resistance to the ground [8]. A choice of $R_6 = 680\Omega$ was made while capacitor $C_5 = 47\mu F$, 50V is selected for feedback DC decoupling. The input DC coupling was calculated using F = 20Hz as:

$$C_4 = \frac{1}{2\pi R_5 F} = 0.36\mu \quad (8)$$

For implementation, C_4 is selected as 1µf to increase input DC coupling. Capacitors C_6 and C_7 (10µf, 50v) are selected as mute time and standby time switching constants. Assuming a stand by time constant of 0.5sec, Time constant;

$$t = RC \quad (9)$$

The Stand by resistance$R_8 = 50k\Omega$. A voltage of 12v is required to switch on the amp from standby. The standby and mute is independently driven by two CMOS logic compatible input pins. The stand by and mute functions are operated by one function and are referred either to GND or +Vs as such diode DS 4148 is selected as a high speed switching diode, to allow current flow in one direction per time. Assuming a mute switching time of 0.25sec and mute time resistance R = 25 kΩ. For implementation $R_8 = 47K\Omega$ and $R_{10} = 27K\Omega$ available values were used, which gives a negligible difference. Assuming a muting voltage of 0.9vand diode output voltage of 0.7v, a choice of R_9 was made as 94.5kΩ. But a standard value of R_9 = 100kΩ is selected for implementation, which gives a negligible difference in function. Capacitor C_{10} and C_{12} are selected as bypass capacitors, $C_{10} = C_{12} = 0.1\mu f$ (typical values).While, C_9 and C_{11} are selected as 4700µf 50v to act as power line bypass capacitor, which is equal to the power supply capacitors. While capacitance $C_8 = 22\mu f$ 50v was selected for boot strapping and R_1 is chosen as 22K such that $C_1 = 1\mu F$ is the preferred value. C is chosen as 47µF 50V to serve as input dc coupling. While capacitor C_3 and C_4 are chosen as 10µF 50V to serve as mute time constant and stand-by time constant. Also, resistor R_4 =47K and R_5 = 33K are chosen as stand-by time constant and mute time constant respectively. The stand-by and mute is independently driven by two CMOS logic compatible input pins. Switching time of the network is 0.02 sec. For minimum offset, input resistance is made equal to feedback resistance R_3 = 22K. This condition ensures that both currents have the same resistance to the ground. The amplification factor for the power amplifier is given as:

$$A_F = \frac{R_1}{R_1 + R_2} = 0.970 \quad (10)$$

The average close loop voltage gain was 30 dB. C_7, C_9, C_6 and C_8 were chosen to serve as supply voltage by pass, while C_7 = 0.1µF, C_6 = 4700µF / 50V, C_8= 4700µF /50V, C_9 = 0.1µF and C_{10} = 0.1µF is chosen to enhance proper output signal filtration and to reduce distortion and increase in output swing. Resistor, R_{11} (2.2Ω) and Capacitor, C_{13} (0.1µF) are selected as a filter network to further smoothen the signal to the output. For the output stage, an 8 ohm, 150 watt woofer is chosen.

The choice of heat sink used is dependent on the thermal resistance of the device which indicates its ability to dissipate heat. The larger the heat, the lower will be its thermal resistance and consequently, the greater will be its ability to cool the power component that is mounted on it.

The overall thermal resistance required for the heat sink is given as:

$$R_T = \frac{T_j - T_a}{P} - \left(T_{j} + T_{m}\right)°C/W = 1.60^0 C/W \quad (11)$$

Where T_j = junction temperature (450^0C), T_a = ambient temperature = 40^0C, P = power =100W

T_{jc} = thermal resistance between junction and case (2^0C), T_{mb} = thermal resistance between component and heat sink = 0.5^0C/W). Therefore a choice of heat sink 170-091 ($R_{TH} = 1.1^0$C/W) is used. Which has a lower thermal resistance than 1.60^0C/W. The circuit diagram for its power supply is shown in figure 5Twhere BR1 = Bridge rectifier, C_{14} = 4700µf 50V, C_{15} = 4700µF, 50V, F_1 = Fuse (2A), T2 = Transformer (25-0-25), PL= AC Cord.

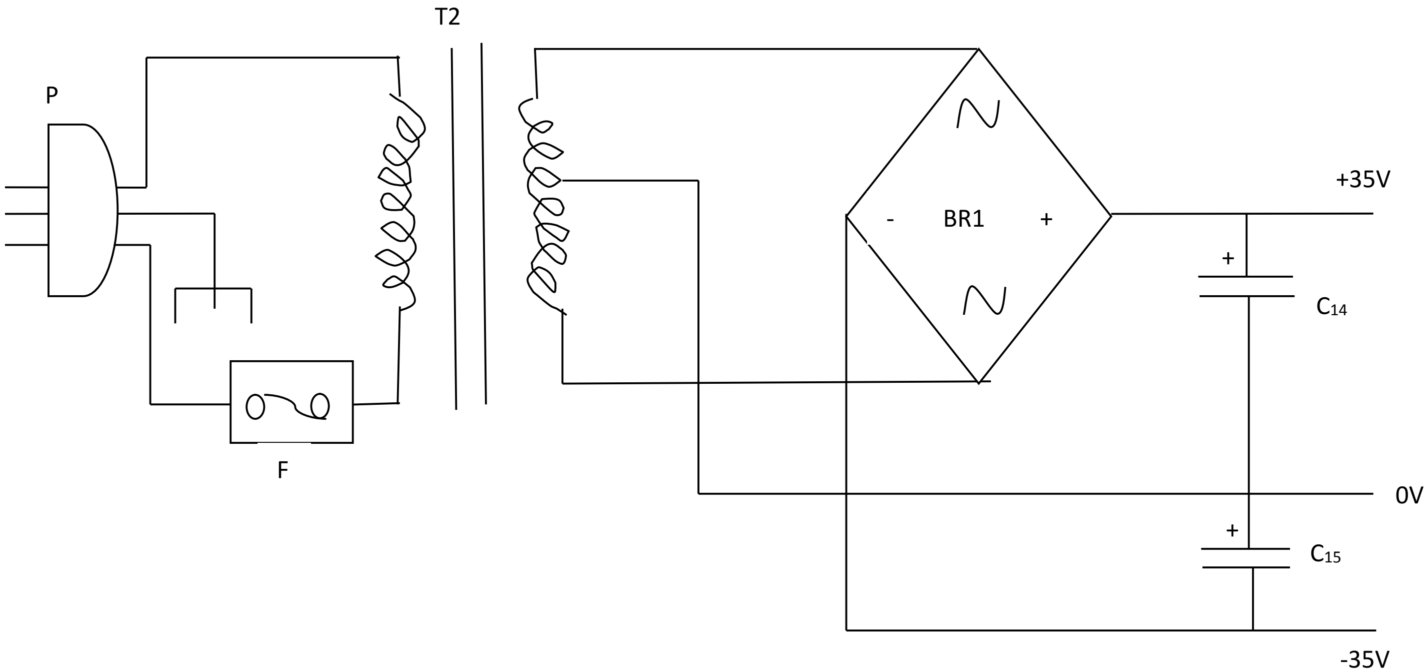

Figure 5: Power supply circuit for power amplifier

For the Power amplifier power supply design, TDA 7294 operates within the voltage range of ± 20v to ±40v while the rail voltage required by the IC to deliver 100 watts to 8Ω load is ±35v dc minimum. Assuming a choice of ± 35v which is ideal for the operation of the circuit [6].A choice of 25v- 0- 25v , 2A Direct current step down transformer was made which according to root mean square relation will give a peak DC output voltage of $\sqrt{2}$ × 25v=35.36v. But for a requirement of 35V, a difference of 0.36V is negligible due to variations in Alternating Current supply per time [7]. Using V=35.36, F=50Hz and I=2A, the filter capacitor, $C=C_{14}=C_{15}$ is expressed as:

$$C = \frac{I(T)}{V} = 1131\mu F \qquad (12)$$

For implementation the filtering capacitors were selected as C14=C15=4700µf 50v to enhance better ripple voltage filtration and to provide for variation in A.C supply voltage. A fuse of I= 1.0A rating was used by applying Ohm's law and assuming Load resistorR_L = 8Ω. While IN4001(4 diodes) rectifier diodes were used.

3.0 Construction, Testing and Result

To effect a neat construction of the circuit designed, a working diagram was produced from the circuit diagrams used. The circuit was first constructed on a breadboard by pushing each component into an appropriate hole by following the circuit diagram after which the circuit was then transferred and constructed on a printed circuit board (Vero board).Continuity test was made on each stage to ensure continuity of conductive parts, insulation test was also made to ensure that nonconductive parts are properly insulated, after which results were observed and taken. For the power supply, ± 12.5V was realized for the pre-amplifier power supply, ±35.6V was realized for the power amplifier power supply and + 12V was realized for the light display power supply.

The Vero board is carefully checked again for mistakes and short circuit since amplifiers are susceptible to problem of feedback and the output could cause a very unpleasant noise (often heard when a microphone is used to close the loudspeaker). Also Positive feedback can occur in this type of circuit when an output load is too close to an input load [5]. To prevent this, the wires are neatly connected and made as short as possible.

The power supply stage was then switched on and the volume control was turned fully clockwise and "signal input" wire is made to contact a wet finger. This gives rise to a faint hum or crackle from the speaker indicating that the amplifier is in order.

A Transistor Radio was also used for the testing by connecting the phone of a transistor radio to the audio in of the amplifier. When the radio is set to a particular frequency, it was discovered that the input signal from the transistor radio was amplified to a larger output via the speaker, which indicates an effective and efficient working condition. Other electronic devices used in the test to obtain a laudable output include Video Cassette player (VCD), Laptop, DVD player, Hand set and a microphone. The power output (p) was measured indirectly using the relation:

$$P = \frac{V^2 e}{R} \qquad (13)$$

Where Veff = rms value from voltmeter, R = resistance and P = power. The meter reading square over the resistance gives the approximate output power of the amplifier as shown in table 1.

Table1: Power output of the 100 watts powered woofer.

V_{cc}	AC MAX RMS	LOAD (SPEAKER)	POWER OUTPUT
±35V	28.28V	8Ω	100W

Efficiency of the Amplifier is given as:

$$E = \frac{A.C\ o \quad p}{D.C\ i \quad p} \times 100\% \qquad (14)$$

Where A.C. output power is the power delivered to the load and the D.C. input power is the power supplied by the D.C. power supply. Under operating conditions;

Supply D.C. voltage = 35v, Supply D.C. current drawn by the amplifier = 4A, D.C. input power = 35 × 4 = 140W and A.C. output power = 100W. Speaker load is treated as purely resistive.

Efficiency = 71.43%.

The power gain of the Woofer is expressed as:

$$G = \frac{P_O \quad (A.C\ o \quad p \quad)}{P_I \quad (A.C\ i \quad p \quad)} = \frac{1 \quad W}{(2 \quad X2)W} = 2 \qquad (15)$$

Power gain A_p = G in decibel= 10 log P_{out} / P_{in}

= 10 log 2 = 3dB.

4.0 Conclusion

A 100 watts powered woofer has been built. The result obtained nearly agreed with the theoretical parameter. The output power with an 8 ohm speaker is 100W. The bandwidth is between 40Hz to 5 KHz. The system is versatile and of economic cost. The current price of its similar type in market is N20,000 while this is N5,000. It also has the advantage of the usage of mute and stand-by function. However, due to the inability to incorporate appropriate filter and distortion tracking circuit, there are some measures of distortion when certain level of input signal is exceeded or maximum input level signal is applied. Also, the total harmonic distortion (THD) cannot be stated precisely for the system. These conditions are allowed owing to the fact that incorporating filter and distortion tracking circuit increases the complexity of the system which is outside the scope of this project, and because of the unavailability of the THD measuring instrument.

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