Design and Development of Audio Amplifier for Music System in Two-Wheeler

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Abstract: ***Audio systems have found their way into all parts of our life. Starting from commercially available high wattage speakers to enjoy music during a social function to car stereos that let the driver pick up and answer a call during busy traffic. It might be the time they find a way into two-wheelers thus allowing the user to enjoy music during a serene long ride or pick up a call while being stuck in busy traffic or even be used with an anti-theft system as alarm to avoid the driver from getting robbed.***

Amplifiers are one of the most widely used electronic circuit almost available in all the electrical utilities today. This project focuses on proposing an audio amplifier compatible with the electrical network of a two wheeler which drives two medium wattage speakers fitted on to the vehicle. There are commercially available speakers that can be installed in some high end vehicles but they also run the risk of drying out the battery because they can be run even when the engine is running.

I. INTRODUCTION

The audio amplifier was invented in 1909 by Lee De Forest when he invented the triode vacuum tube. 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.[1]

Early audio power 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), but there are still some who prefer tube-based amplifiers, and the valve sound. Audio power amplifiers based on transistors became practical with the wide availability of inexpensive transistors in the late 1960s.

The audio amplifiers became a part of everyday-today life appliances. And they were designed accordingly as per the requirements of the device and parameters. Various brands such as Leoie, Boss, PAGARIA and Allextreme manufacture and sell audio systems on online shopping platforms for higher end two-wheeler vehicles. Facilities such as Bluetooth and Aux connectivity with Radio, FM and Anti-theft alarm built in.

This report proposes a design of audio amplifier to drive medium wattage speakers fitted in two wheelers during engine ignition condition with optimal bandwidth, power efficiency, compact size and least distortion. The amplifier is driven by a battery having same parameters of that available in typical 2-wheeler vehicle (12V). The amplifier drives two medium speakers (4Ohm, 10W) connected in series. The design uses multistage amplifier (One preamplifier and one power amplifier). The preamplifier uses a class-A amplifier operated to amplify the received signal linearly before being amplified by the power amplifier which consists of a AB push-pull stage biased by the use of diodes. Input to the amplifier is given at the base if class-A biased Bipolar Junction Transistor through a coupling capacitor. The output of the signal is fed to the bases of two bipolar junction transistors which are class-AB biased by using diodes for constant voltage drop connected to the collector of the class A biased BJT.

DESIGN PARAMETERS

We use typical battery available in motorcycles of six cells each of 2.1V thus giving an overall 12.6V power supply. The design compromises with the efficiency of the device to trade off with quality of sound produced and linearity of the signal.

It was ensured that the audio system was only operational when the engine was running. This was done by using power distribution block which cuts off the supply when the engine is turned off.

II. BLOCK DIAGRAM

Given below is the block diagram if the proposed design. The signal is received by the system from a device via any form of communication (Bluetooth, AUX etx.) which is then fed to an Digital to analog converter that converts the signal received from the device to analog audio signal of consisting of audio frequencies (20Hz to 20kHz).

The signal is received is of varying voltages of range 0-1V. This shall be taken into account while biasing the proceeding pre-amplifier. The signal is fed to the pre-amplifier from DAC via a volume control which is made up of a Rheostat consisting of a series of high resistance resistors with connection points so as to control the volume by varying the volume of signal input. The signal is then fed to a power amplifier which amplifies the power of the signal amplified by the pre-amplifier. The output produced from the power amplifier drives the speakers. The speakers consist of coils on top of permanent magnets which move with the varying current fed.

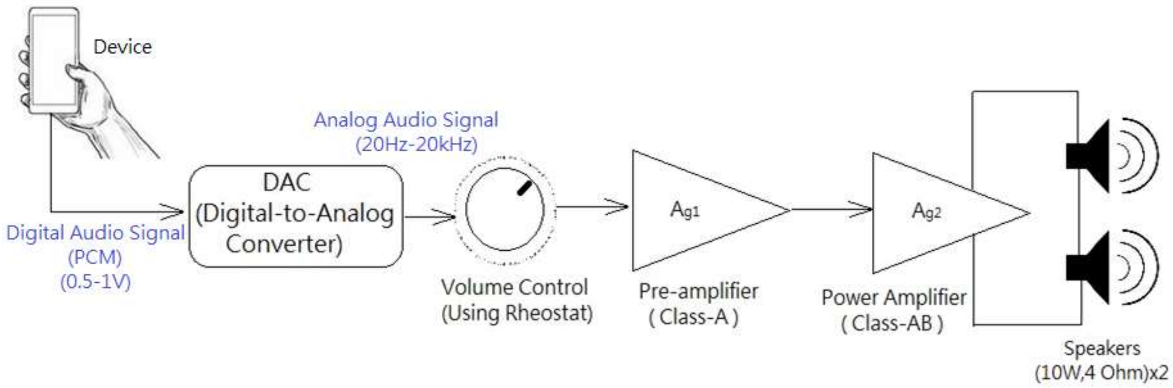


Fig 1: Block diagram of proposed design

III. CIRCUIT DESIGNED

I. Pre-Amplifier Circuit

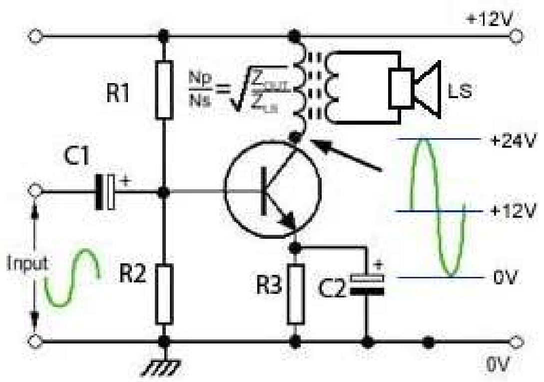


Fig 2: Class-A biased BJT amplifier circuit

We use a class-A biased BJT transistor as pre-amplifier circuit for initial amplification of the signal received from the device. The purpose of class A bias is to make the amplifier relatively free from distortion by keeping the signal waveform out of the region between 0V and about 0.6V where the transistor's input characteristic is non linear. Class A design produces good linear amplifiers, but is wasteful of power. The output power they produce is theoretically 50%, but practically only about 25 to 30%, compared with the DC power they consume from the power supply.

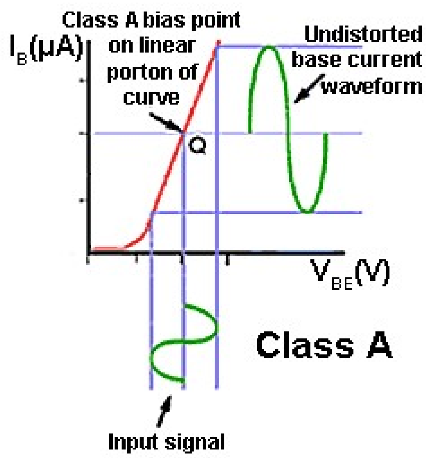


Fig 3: Class-A amplifier current-voltage characteristics

Class A power amplifiers use the biasing method illustrated in Fig.3. This method causes a standing bias current to be flowing during the whole waveform cycle, and even when no signal is being amplified. The standing bias current (the Quiescent Current) is sufficient to make the collector voltage fall to half the supply voltage, and therefore power ($P = I_C \times V_{CC}/2$) is being dissipated by the transistor whether any signal is being amplified or not. This was not a great problem in class A voltage amplifiers, where the collector current was very small, but in power amplifiers output currents are thousands of times larger, so efficient use of power is crucial.[2]

II. Power Amplifier Circuit

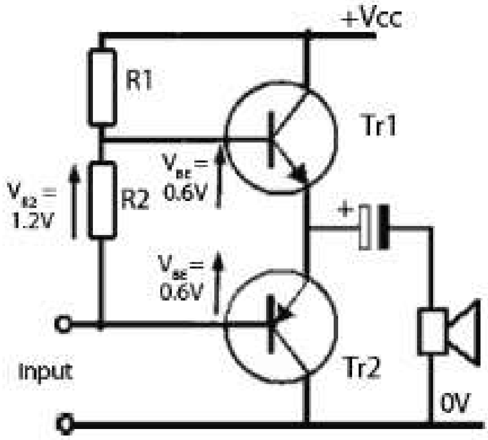


Fig 4: Class-AB push-pull stage BJT amplifier circuit

We use a class AB push pull stage for power amplification of the signal received from pre-amplifier. The class AB push-pull output circuit is slightly less efficient than class B because it uses a small quiescent current flowing, to bias the transistors just above cut off as shown in Fig. 5.5.1, but the crossover distortion created by the non-linear section of the transistor's input characteristic curve, near to cut off in class B is overcome. In class AB each of the push-pull transistors is conducting for slightly more than the half cycle of conduction in class B, but much less than the full cycle of conduction of class A .

As each cycle of the waveform crosses zero volts, both transistors are conducting momentarily and the bend in the characteristic of each one cancels out.

Another advantage of class AB is that, using a complementary matched pair of transistors in emitter follower mode, also gives cheaper construction. No phase splitter circuit is needed, as the opposite polarity of the NPN and PNP pair means that each transistor will conduct on opposite half cycles of the waveform. The low output impedance provided by the emitter follower connection also eliminates the need for an impedance matching output transformer.

Matching of current gain and temperature characteristics of complementary (NPN/PNP) transistors however, is more difficult than with just the single transistor type as used in class B operation. Also with no emitter resistors, due to the use of emitter follower mode, temperature stability is more difficult to maintain. Class AB therefore, can have a greater tendency towards thermal runaway.

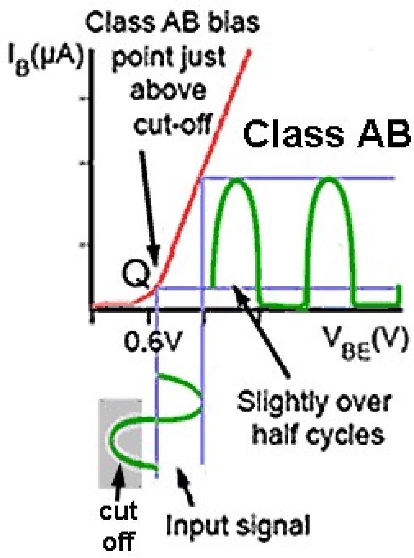


Fig 5: Class-AB amplifier current-voltage characteristics

Fig 5 illustrates the method of applying the class AB bias to a complementary pair of transistors. The two resistors R1 and R2 apply voltages to the output transistor bases so that Trl (NPN) base is about 0.6V more positive than its emitter, and Tr2 (PNP) base is about 0.6V more negative than its emitter, which is at half of V_{CC}.

To overcome crossover distortion, the bias on the base of each transistor needs to be accurately set so that the transistors will begin to conduct as soon as their respective half cycle begins; it is therefore common for R2 to be made adjustable.

3. Overall Designed Circuit

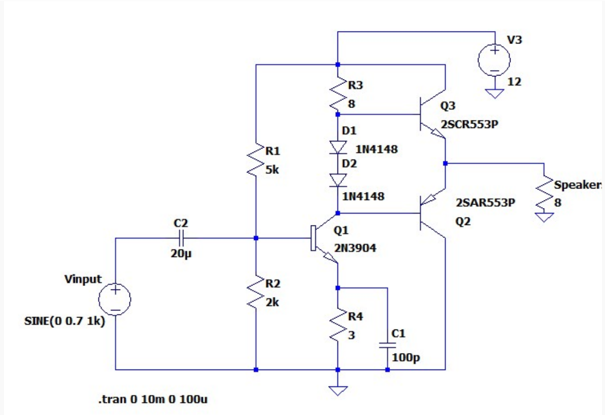


Fig 6: Audio amplifier circuit designed

Components required for amplifier design

- Resistors(2kΩ, 5kΩ, 3Ω, 8Ω)
- Bipolar Junction Transistor(2SCR553P, 2SAR553P, 2N3904)
- Diodes(1N4148) x2
- Capacitor(20uF)
- 12V voltage source
- Speakers (10W ,4Ω) x2

The signal fed from the dice is fed via a volume control circuit to the power amplifier via a coupling capacitor. The coupling capacitor (20uF) ensures that the preceding circuit is not affected by the DC voltage applied at the base of transistor Q1.

The transistor Q1 is biased using a voltage divider circuit of 2kΩ and 5kΩ. The voltage at the base of transistor Q1 being 1.6V to ensure the maximum input voltage V_{be} swing of 1V lies in the linear range of amplification. The emitter bypass capacitor is connected to give a low resistance path at high frequency.

The output at collector of transistor Q1 is used to forward bias diodes D1 and D2 which are again used to bias the power amplifier to class-AB push pull output stage configuration. The matching PNP and NPN configuration are used to amplify the positive and negative halves of the cycle respectively.

The amplified output of power amplifier is used to drive the two speakers of 10W, 4Ω. The speakers are driven by varying current which moves the coils on the permanent magnet to push air out of the speaker to produce the sound.

IV. OBSERVED OUTPUTS

To observe the generated output we consider an intermediate frequency of 0.7V and an intermediate frequency of 1kHz. After simulation all the intermediate outputs were observed and verified.

1. Output Frequency

Fig 7: Frequency of the output generated

The output frequency was observed as above. An error of 3.125kHz was detected which can be analysed to human calculation error due to lack of an automated tool to calculate frequency.

2. Output Voltage

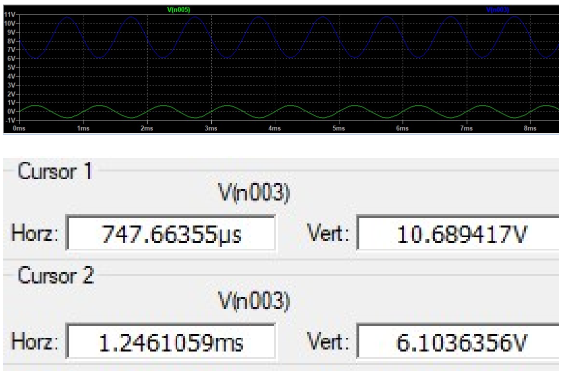


Fig 8: Voltage output generated

A voltage swing of 10.689V-6.103V was observed across the speaker. Thus giving us an voltage amplification of 6.55 V/V i.e. 16.32bB.

3. Current Output

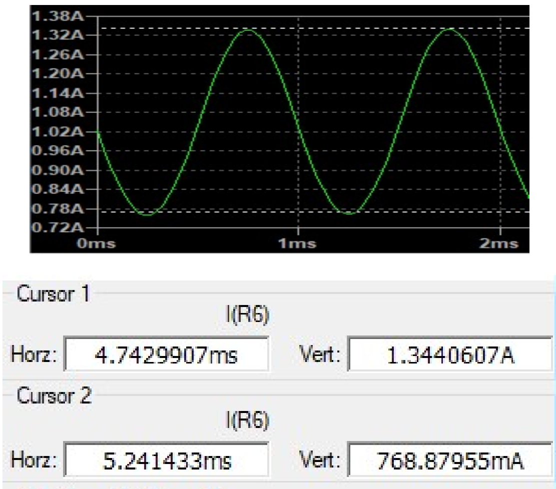
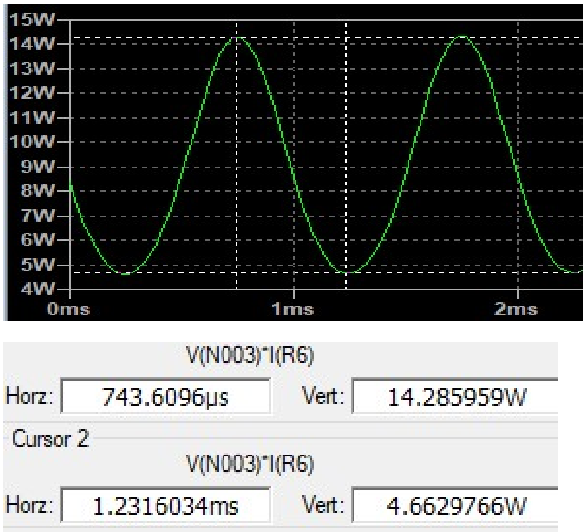


Fig 9: Current output generated

A current swing of 1.344A-0.768A was observed across the speaker.

4. **Output Power**



A power swing of 14.286W-4.663W was observed across the speaker. The power supplied by the voltage source being 48W. Thus giving us an efficiency of 29.76%.

V. PROBLEMS FACED DURING DESIGN

- Unable to produce required current swing.
- Wastage of power in biasing resistors.
- Unavailability of matching NPN-PNP power transistor pair for Class-AB amplifier.
- Clipping of signal and other forms of distortion

Implemented Solutions

- Use of pre-amplifier prior to power amplifier.
- Use of high resistance resistors to provide biasing to transistors and ensure low current.
- Use of TIP31A and TIP32A during real-time implementation.
- Choosing coupling and decoupling capacitance based on input and output impedance respectively.

VI. Probable Errors during real-time implementation

- Fluctuation of voltage supply from battery during operation.
- Loading effect between speaker and amplifier circuit.
- Attenuation of signal at low frequencies.

Proposed Solutions

- Supplying voltage supply to the circuit parallel to a capacitor of high capacitance value (high time constant value) to maintain steady voltage supply.
- Supply output to speaker via transformer.
- Selection of coupling capacitor such that attenuation does not occur in audio frequency range

VII. FUTURE SCOPE

- Efficiency of the amplifier can further be improved by reducing the standing current when no signal is applied.
- Better gain can be produced by implementing matching PNP and NPN transistors (TIP31A, TIP32A).
- The developed module can also be implemented for anti-theft alarm.

VIII. REFERENCES

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Software Used- LTSpiceXVII by Analog Devices