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Development of an Audio Power Amplifier for the Management of Speaking Activities

Chibuike Chukwuma Onwubiko, Abiodun Alani Ogunseye, Ayodeji Olalekan Salau and Thomas Kokumo Yesufu

Abstract— This study developed and evaluated the performance of a method of reducing the quiescent energy consumption in conventional class AB audio power amplifiers, which are commonly used in public address systems.The structure of a conventional class AB audio power amplifier was modified to allow it to be successfully and profitably timed via a dynamic selection of a low power mode. The resulting audio power amplifier circuit was modeled with MULTISIM®. A microcontroller circuit, used to control the audio power amplifier in response to user timing commands and presence or absence of audio signals, was also designed and modeled with Proteus® software, and then constructed to bring about a reduction in the quiescent power requirement of the audio power amplifier by a factor of 1000.

Index Terms— Audio amplifiers, Energy, Facilities management, Green economy, Human-Machine interaction, Material informatics, Microcontrollers, Public address systems, Simulation

1.0 Introduction

Materials informatics is a field of study that applies the principles of informatics to better understand the use, selection, development, and discovery of materials in all ramifications [1]–[3]. The domain of material informatics includes facilities management, which focusses on the cost-effective combination of resources and activities. A common resource that has been poorly integrated with the human activity of speaking is the audio amplifier, which ultimately results in energy inefficient systems and operations [4].

The energy efficiency of electronic equipment has always been of engineering interest, for example, in the design of battery-powered devices. Like other electronic systems, audio power amplifiers draw electric power from a direct current (d.c) power source before they can do any useful work. Conventional class AB public address systems waste significant amount of power in their avoidable idling modes which eventually leads to higher operating cost of ownership of the equipment [4], [5]. Class AB amplifiers exhibit lower levels of crossover distortion, but they are not as efficient as class B amplifiers, due to the quiescent power dissipation. Class AB amplifiers have a good compromise between distortion and efficiency. Class AB amplifiers must be biased into quiescent conduction to reduce crossover distortion. This causes a drop in the efficiency of the power amplifier, resulting in an increased need for a microcontroller-based management of the operational cost of the equipment.

Microcontrollers, which is based on a combination of technology and economics, are often used in automatically controlled products and devices, such as automobile engine control systems, remote control units, office machines and control applications [6]. Accordingly, a microcontroller is a small computer on a single integrated circuit, consisting of a relatively simple central processing unit (CPU), program memory, data memory and some peripheral devices such as crystal oscillator, timer, watchdog timer, serial communication port, and analogue to digital converters (ADCs).

In this paper, a power saving audio power amplifier was designed. A microcontroller, PIC16F877A, implementing a simple state machine was used to control an audio power amplifier circuit in response to silence intervals in the input speech signal which is detected by a simple audio detection circuit. The microcontroller circuit puts the class AB audio power amplifier in a low power mode when the silence interval in the input speech signal exceeds a preset time of about 3 seconds or more. In addition, the duration of use of the audio power amplifier can be specified by the user and when this time elapses, the audio amplifier is put in a low power mode. These features ensure a better integration of the audio amplifier with the act of speaking and, hence, an attendant reduction in the quiescent energy consumed by the audio power amplifier.

The remaining sections of the paper are Sections 2, 3 and 4, which respectively describes the steps leading to the design and testing of a microcontroller-based class AB audio amplifier circuit, a discussion of the results obtained and a conclusion of the paper.

2.0 Methodology

A typical class AB audio amplifier circuit, which follows [7] and [8], is illustrated in Figure 1. In addition to the normal audio input port, the amplifier has another input port that puts the amplifier into a low power mode when asserted. Also, an audio preamplifier and an audio detection circuits were designed and constructed. A microcontroller based circuit was

- Chibuike Chukwuma Onwubiko has completed his masters degree program in electronic and electrical engineering in Obafemi Awolowo University, Ile-Ife, Nigeria, E-mail: onchybyke@yahoo.com
- Abiodun Alani Ogunseye is currently prsuing a doctorate degree program in electronic and electrical engineering, E-mail: abbeyogunseye@gmail.com
- Ayodeji Olalekan Salau is currently pursuing a doctorate degree program in electronic and electrical engineering, E-mail: toupside@yahoo.com
- Thomas Kokumo Yesufu is a Senior Lecturer in the department of electronic and electrical engineering, Obafemi Awolowo University, Ile-Ife, Nigeria, E-mail: thomas_yesufu@yahoo.com

used to control the audio power amplifier. The microcontroller circuit features a keypad and an LCD unit for accurate timing

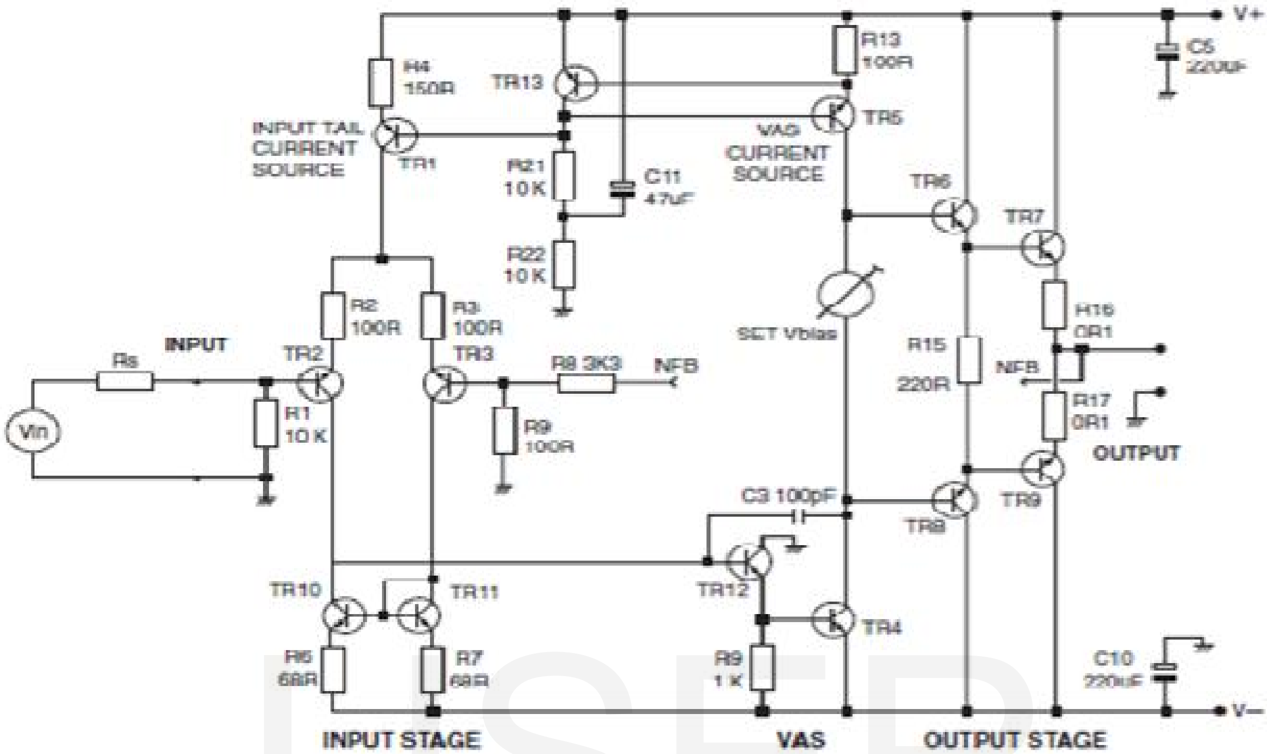

Figure 1: Class AB Audio Power Amplifier [12]

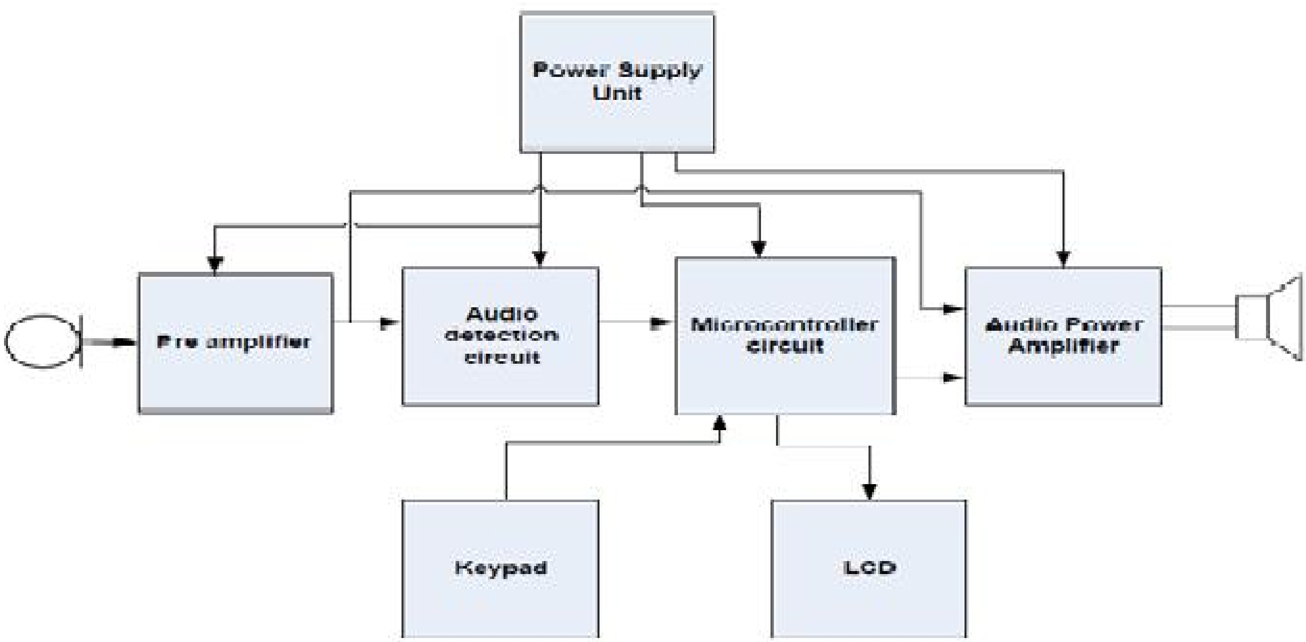

Figure 2: Block Diagram of Hardware Layout of the Project.

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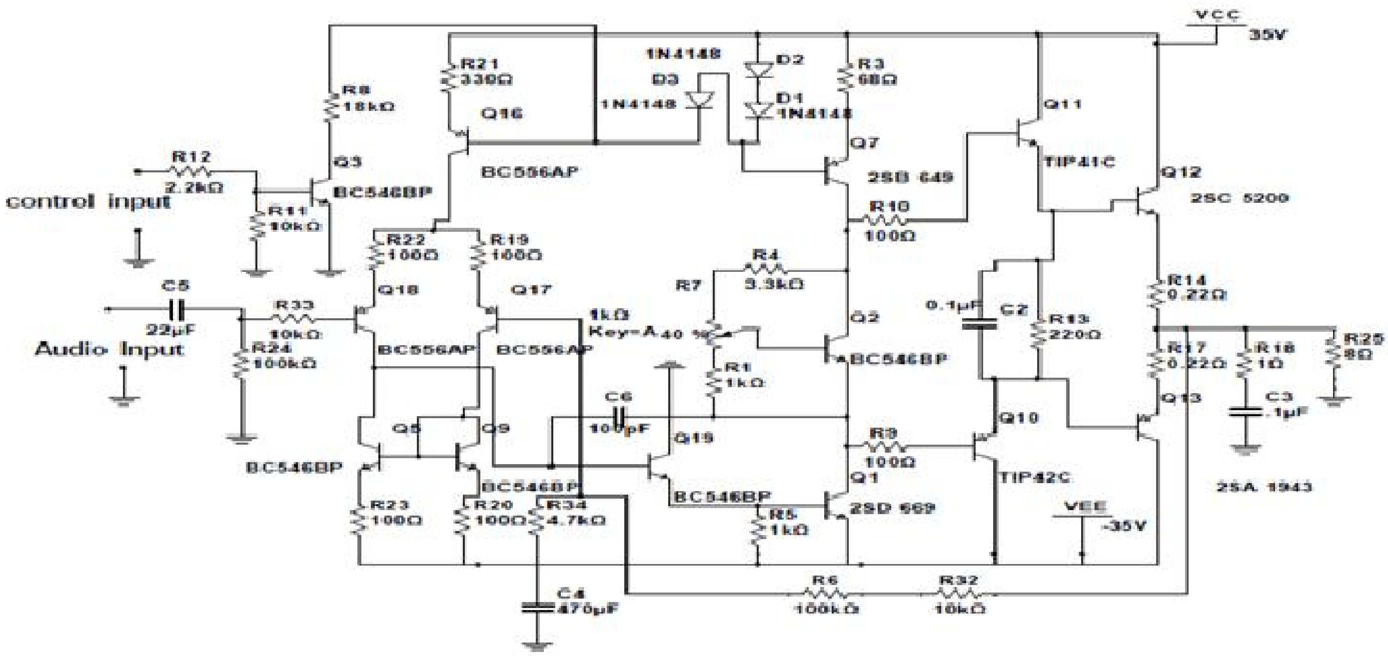

Figure 3: Audio Power Amplifier with Shut Down Input.

and display of the state of the audio power amplifier. This is illustrated in Figure 2.

The schematic diagram of the audio power amplifier is as shown in Figure 3. The audio power amplifier is a conventional power amplifier with an additional control input port. All the operating bias currents of the amplifier were derived from the sum of the forward bias voltage of diodes D1, D2 and D3. Switching transistor Q3 was used to control the bias current flowing through the bias generating diodes. Thus, the entire amplifier can be put in a low power mode by applying the appropriate logic signal to the control input of the amplifier [9]. The mid-band voltage gain of this power amplifier is determined by the values of resistors R32, R6 and R34 in Fig. 3 and it is set to 24.4 V/V.

2.1 Audio detection circuit

This circuit generates a digital output signal when an audio signal is detected at its input. The circuit consists of an active full wave rectifier circuit and a comparator. Figure 4 shows the audio detection circuit. The active full wave rectifier circuit consists of an inverting summer, built around U2B, and a half wave rectifier circuit designed around U1A. This circuit is described in [10]. Diode D2 was included in the half wave rectifier circuit to ensure fast recovery of the circuit when a negative input voltage is applied [11] (Ducu, 2011).

2.2 Microcontroller-based circuit

The microcontroller-based circuit, developed with Proteus® software, consists of a keypad, an LCD, a PIC16F877A microcontroller and other basic electronic components like resistors and capacitors. This circuit enables or disables the audio power amplifier, based on the timing parameter entered through the keypad and the presence or absence of the audio signal from the preamplifier. The circuit is shown in Figure 5.

The microcontroller runs a simple finite state machine to determine its response to the input audio signal when the keypad is not pressed. The state machine is illustrated in Figure 6. If the amplifier is enabled, it will remain enabled as long as the input audio signal is present. If no audio signal is detected, the circuit waits for a period of 3 seconds before switching off the amplifier. If the amplifier is disabled, the circuit enables it as soon as audio signal is detected at its input.

The circuit allows the operator to set the time duration in which the audio amplifier will respond to the input audio signal. The operator enters this time (in minutes) and then presses the 'enter' key. The circuit will then proceed to enable the audio amplifier for this duration. At each instant, the state of the audio power amplifier and the remaining time duration will be displayed on the LCD. When this time duration lapses, the circuit disables the audio power amplifier and then prompts the operator to press the 'enter'key before enabling the amplifier. Figure 7 shows the flow chart of the microcontroller software.

The system was developed using mikrobasic software. The circuit was designed and simulated using Proteus software.

3.0 Results and Discussion

A sample of the output waveform produced by the MULTISIM model of the enabled audio power amplifier circuit when an input sinusoidal signal of 1 volts amplitude and a frequency of 2 kHz is shown in Figure 8a. With the amplifier disabled, no output signal was observed, as illustrated in Figure 8b.

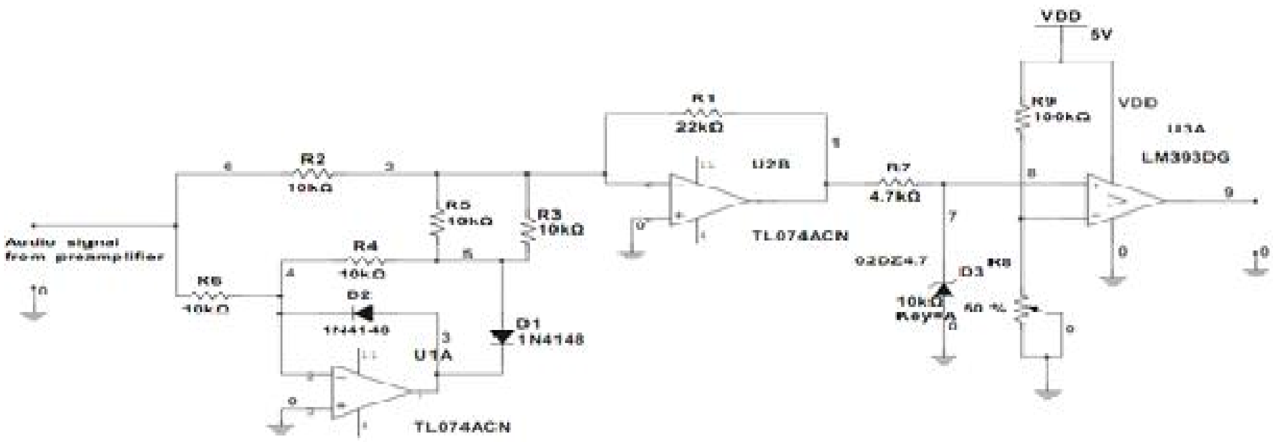

Figure 4: Audio Signal Detection Circuit

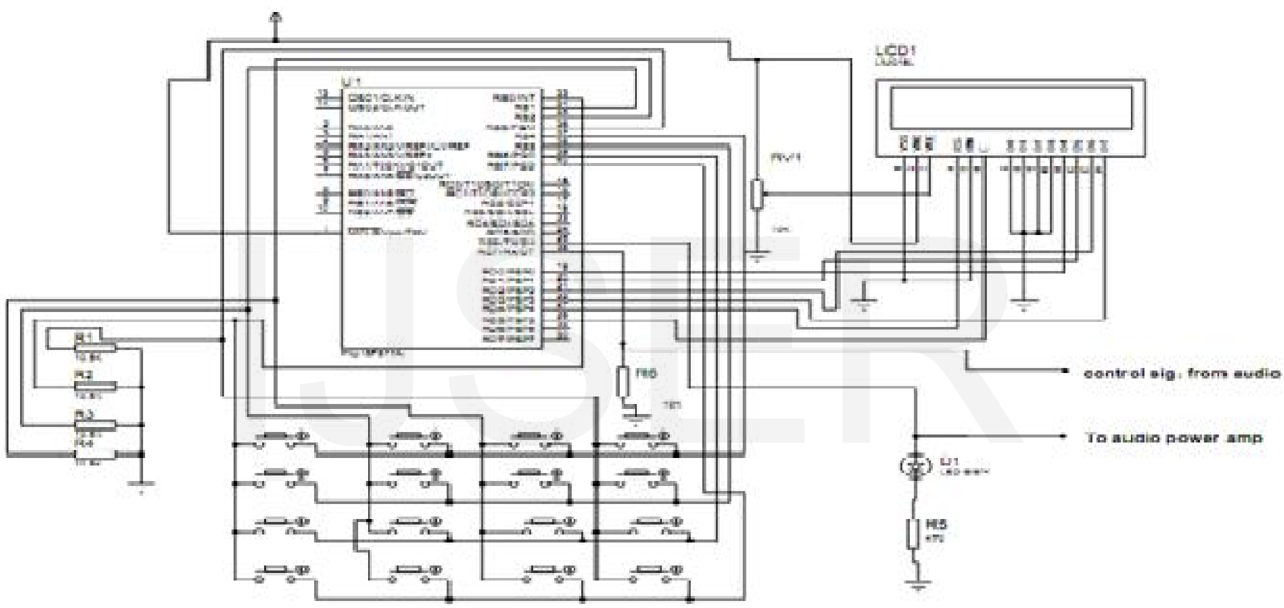

Figure 5: The Microcontroller Circuit.

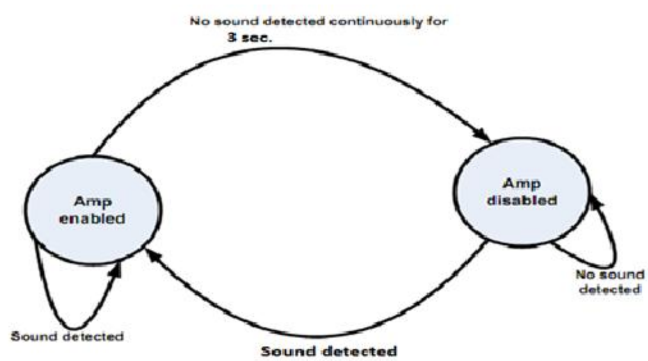

Figure 6: Finite State Machine Run by the Microcontroller Circuit when Keypad is not Pressed.

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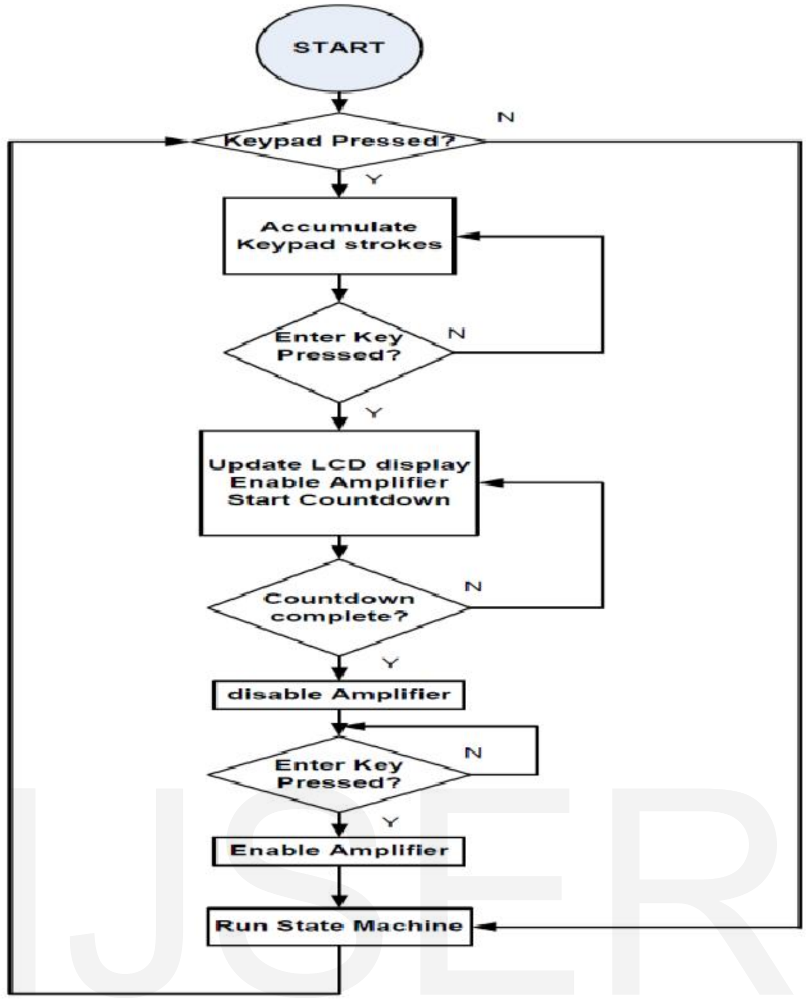
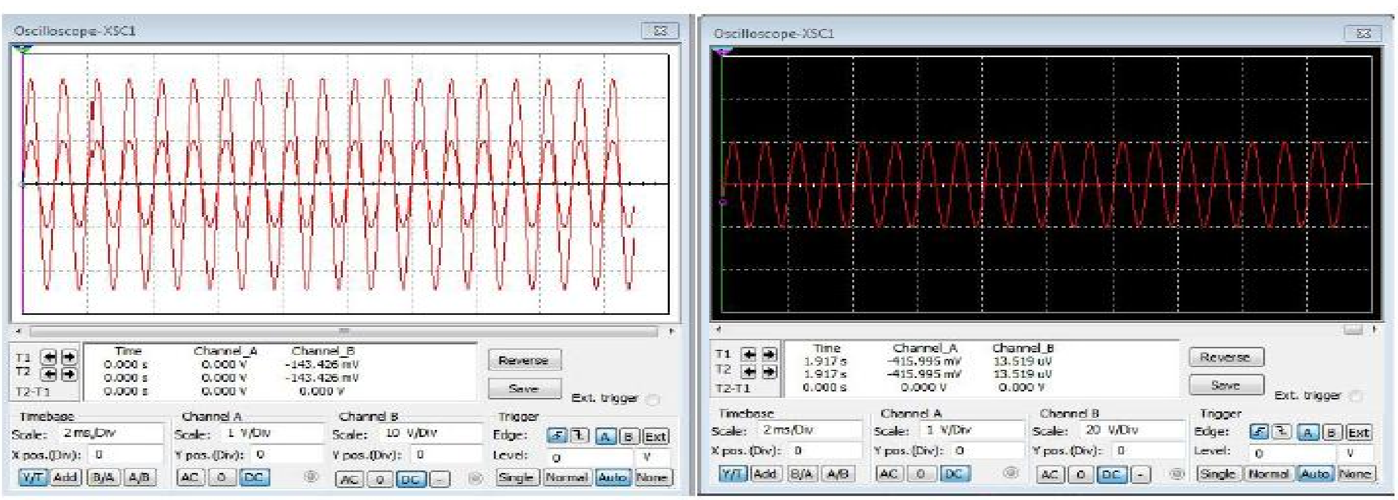


Figure 7: Flowchart of the Microcontroller Program.



a) b)

Figure 8: The Input and Output Waveforms of the Amplifier Model when (a) Enabled and (b) Disabled.

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The currents drawn from the power supply sources by the constructed audio power amplifier circuit were measured with two milliammeters, with each milliameter connected in series with the positive and negative power supply rails of +35 V and -35 V respectively. The output transistors were biased into class AB mode of operation by varying potentiometer R7 (Figure 3) until the quiescent current was 100mA and thus, a quiescent power of 7 W. With the amplifier disabled, the currents drawn from the positive and negative supplies were 40µA and 160µA respectively (which corresponds to a power dissipation of 7mW.

It was, therefore, possible to put the prototype audio power amplifier circuit into a low power mode when no audio signal was detected in the input channel. This brought about a reduction in the quiescent power requirement of the audio power amplifier by a factor of 1000.

4.0 Conclusion

The resource-activity or structure-property relationship of a conventional class AB audio power amplifier was modified to successfully create a flexible duration low power mode and, hence, allow for its dynamic and profitable selection. This involved deriving all the operating currents of the amplifier from a diode-based reference source. A microcontroller circuit, used to control the audio power amplifier in response to user timing commands and presence or absence of audio signals, was also designed and modeled using Proteus® software, and then constructed. It was possible to put the prototype audio power amplifier circuit into a low power mode when no audio signal was detected in the input channel, resulting in reduced quiescent power dissipation. A significant reduction in the quiescent energy requirementof a class AB audio power amplifier was brought about by the microcontroller-based sensing and timing of its operations. The developed system would therefore bring about improved public address systems for use in organizing structures for free speeches and debates in institutions where the property of equal rights and justice are demanded from speaking facility managers.

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