Design and Construction of Multi-input Audio Mixer

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Abstract

Due to exorbitant prices, difficulty in operation, and high cost of maintenance of existing audio console, a simple, efficient, and cost-effective multi-input audio mixer has been designed and constructed. A simple design achieved this with three sections: power supply, pre-amplifier, and power amplifier sections. The audio console was designed with a high-grade operational amplifier with very low distortions. The power supply section was constructed by connecting the secondary terminals of *12 V* transformers to a bridge rectifier for optimum power supply to the system. The pre-amplifier section was constructed using a *BC547* NPN transistor. The power amplifier was constructed using the *LM386 IC* for high-quality output. The design carefully combined (audition/program) units to achieve good mixing and balancing. The design was done to achieve a maximum gain with refined audio output.

1. Introduction

Audio mixer also called a sound board or mixing console is an electronic device for combining routing and changing the level of audio signals [1]. Analog or digital signals can be mixed by audio-mixer to produce the combined output signals. It is a complicated group of circuit elements such as transistors, regulators, capacitors, operational amplifiers, etc.

The audio mixer is applied in many areas such as: sound reinforcement systems, recording studios, television, broadcasting, public address systems and film post-production [2]. A simple application of mixer could be to enable the signals that came from two separate microphones to be heard simultaneously via one speaker.

An operator at the control board can switch to any of the above-mentioned devices. With the gain controls also known as faders, attenuators, or pots (potentiometer), the amplifier amplitude of the program can be varied to keep the highest peaks of modulation above the required *85%* and below *100%* modulation on the negative peaks.

The console can also be used to mix two or more inputs as in the musical or recording industry. The instruments are switched with their gain control properly leveled with the microphone of the vocalist. Similarly in the broadcasting industry, some adverts or programs have musical background and most at times more than one input is required. The console is used through the gain control to level the background, other inputs and the adverts such that music remains only as the background and can be lowered or increased when needed. To minimize audio feedback, public address systems can use mixing console to set microphones for different speakers to the correct level, and also add recorded sounds into the mix [3].

The console could also be used as intercom (a system of communication by telephone or radio inside an office) between the presenter in the studio and the operator in the control room. This enables the operator to know exactly when to switch on or engage the presenter's microphone and proper timing is achieved.

The program output and the audition output both are combined to give high-quality output. Frequency modulation (FM) will result if the output of an oscillator is applied to control the frequency of another oscillator. The oscillator providing the signal is referred to as the carrier. Sub-audio frequency modulation or vibrato will result if the modulating oscillator is tuned below audio-rate (or approximately 20Hz). As the modulating waveform rises (increases in amplitude), so too will the frequency of the carrier. LM 386 is ideal for battery operation due to the fact that the quiescent power drain is only 24 milliwatts when operating from a 6 volts supply [5].

Due to exorbitant prices, difficulty in operation, and high cost of maintenance, the existing mixers are not readily available to average sound engineers. These challenges necessitate this work focused on the design and construction of a moderate, easy to operate, light weight, inexpensive, reliable and durable, audio console (mixer). The formulas used in this work for analysis came from the following literatures [7-10].

2. Materials and Methods

This section presents meticulously the configuration of the components to achieve the set objective of this research. Analysis and mathematical derivations of any section or unit will be given where such analysis is necessary and can help to quicken understanding.

2.1 Block Diagram of Audio Console

The different stages are coupled in the block diagram as shown in Fig. 1.0:

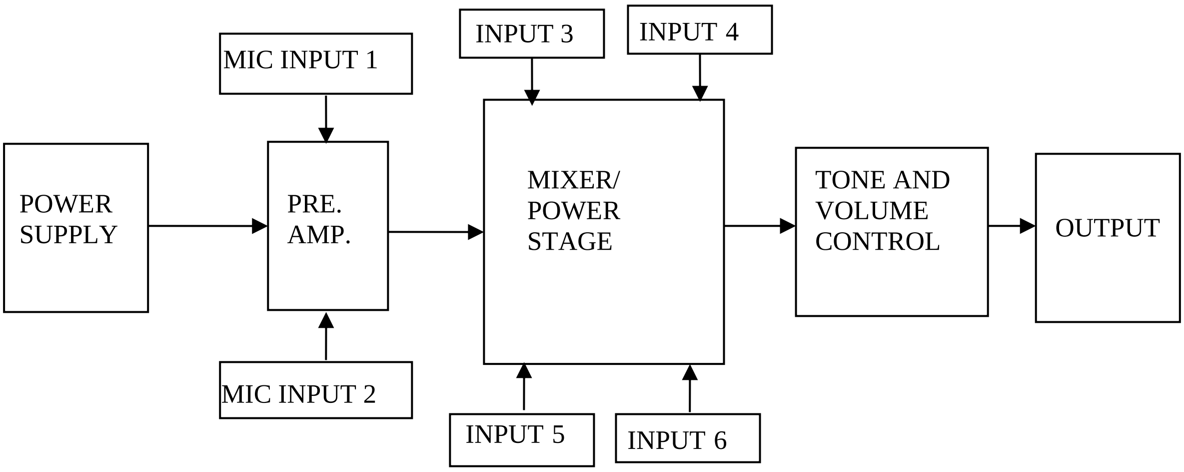

Fig.1.0 Block diagram of multi-input Audio –mixer

2.2 Power Supply Unit

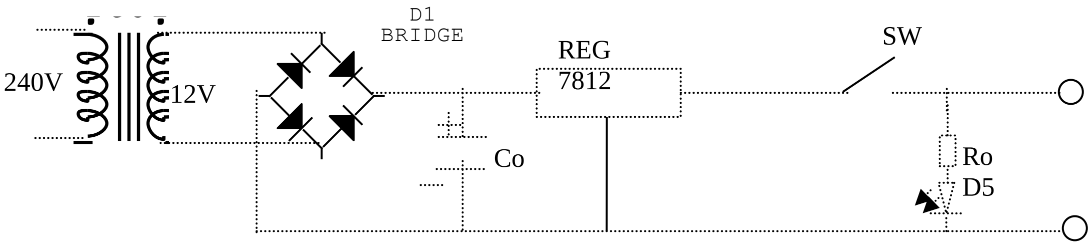

Fig. 2.0 Power Supply Section Circuit diagram

The capacitor value is chosen so that

$$R_{load}\, C \geq \frac{1}{f} \qquad (1)$$

(Where f is the ripple frequency)

$R_{load} = 80ohms$

$f = 50Hz$

$C \geq 1/R_{load} f$

$\geq 1/8 \times 50\ F = 1/400F = 2500\ \mu F$

$C \geq 2500\ \mu F$.

The transformer receives power at one voltage and delivers it at another. It consists of two closely coupled coils (called primary and secondary). An AC voltage applied to the primary appears across the secondary, with a voltage multiplication proportional to the turn's ratio of the transformer and a current multiplication inversely proportional to the turn's ratio. [6]. TF is a step-down transformer rated *240V-12V*, *500mA*. Bridge rectifier D_1-D_4 is used to rectify the AC voltage. They are general purpose diode (*IN4001*). The resulting dc voltage charges the smoothening capacitor *C*, to its *rms* value. The value of the dc voltage is thus given as

$$V\,dc = \sqrt{2} X\ V\,ac \qquad (2)$$

$$= 12\ X\ \sqrt{2}$$

$$V_{dc} = 16.97V_{dc}$$

A large value capacitor C_o is used to reduce the ripple voltage to a minimal level. A red light emitting diode (LED) is used to signify power ON or OFF.

$$R_o = V_s - \frac{V_d}{I_{max}} \qquad (3)$$

$$V_s = V\,d_c = 16.97V\,d_c \qquad (4)$$

V_d = voltage drop by diode = 1.6V

I_{max} = Maximum load current of red LED 20mA

$$R_o = 16.97 - 1.6\ /20\ X\ 10^3$$

$$= 15.37/20\ X\ 10^3$$

$$R_o = 769\ ohms$$

7812 is a *12V* regulator used to ensure a constant *12V* dc supply to the system. D_5 is red LED used to indicate power ON or OFF. SW is the power switch for turning ON and OFF of the system.

2.3 The pre-amplifier stage

The pre-amplifier (pre-amp) stage Fig. 3.0 is a section in the audio-mixer where the mic-input is first amplified. This work uses an emitter amplifier BC547.

The diagram of pre-amplification stage for mic-input is given in Fig. 3.0

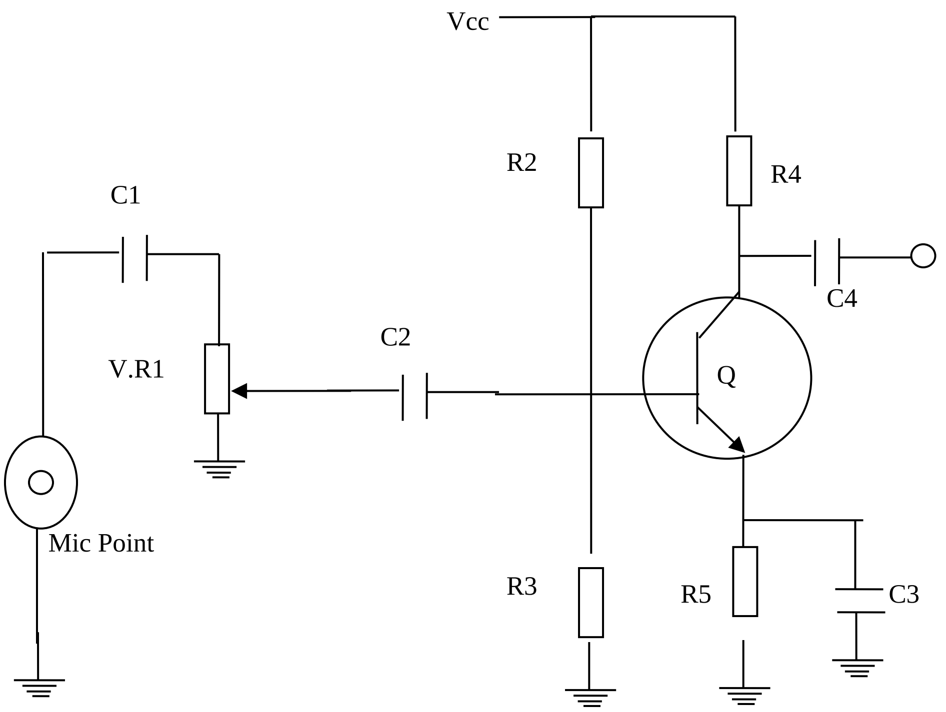

Fig.3.0 Pre-amp stage of audio mixer

A voice signal is fed through the mic port, the filtering capacitor filters the sound and the transistor Q_1 amplifies the signal. The values of the components are given below.

C_1 = *1000 µf*

C_2 = *10 µF*

C_3 = *10 µF*

C_4 = *10 µF*

R_2 = *82 k*

R_3 = *10 k*

R_4 = *7.5 k*

R_5 = *1 k*

$V.R_1$ = *100 k*

Q_1 = *BC547*

C_1 is a filtering capacitor; it filters the voice signal from the microphone. $V.R_1$ is the variable resistor also known as the volume control. It is used to control the voice signal from the microphone. $C_1$and C_4 is coupling capacitors. C_3 is a bypass capacitor selected by making impedance small when compared with Re (intrinsic emitter resistance) at the lowest frequency of interest. R_e is a bypass resistor which is about 0.1R_c; for ease of biasing. R_4 is the collector resistor chosen to put the quiescent collector voltage at 0.5Vcc. R_2 and R_3 are voltage divider resistors used to hold the base at constant voltage.

The gain is $G \;=\; -\,gmRc \;=\; -\frac{Rc}{re}$ (5)

$$= -Rc\; IC(mA)/25$$

In this project BC547 npn transistor is used. And it is a general purpose transistor. The collector current (I_c) is *2(mA)* and the gain is i.e. $B = 200$

The gain G of the single stage grounded emitter amplifier is

$$G = -7.5 \times 1000 \times 2 / 25$$

$$G = -600$$

Also gain is given by

$$G = V_o/V_{in} = 600$$

In decibel (db)

$$Gain\ (db) = 20\ log10\frac{V_2}{V_1} = 20log10\ G \quad (6)$$

$$= 20log10\ 600$$

$$= 55.6$$

2.4 Power/Mixer Amplifier Stage

The power/mixer amplifier stage Fig 4.0 is achieved by the use of LM386 IC. The IC is a low voltage device, designed to work with a dc supply in the range of *4* to *12V*, when used without external gain components, across pins 1 and 8. This chip's gain is internally set at *20*. By use of the external capacitors and resistors, the gain can be adjusted to any range. The circuit diagram for the power/mixer stage is given below

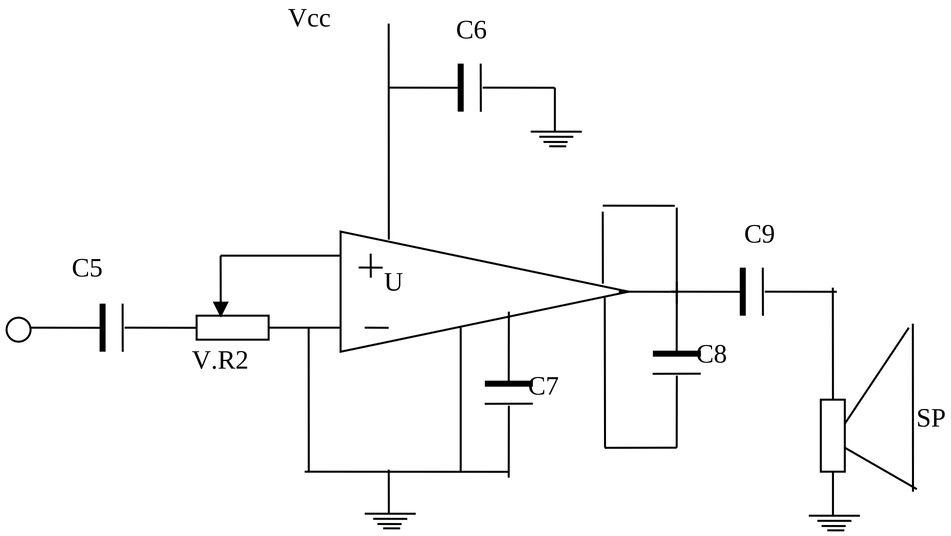

Fig. 4.0 Power/mixer Amplifier circuit

The components values are listed as follows

$C_5 = 47\ \mu F$

$C_6 = 1000\ \mu F$

$C_7 = 10\ \mu F$

$C_8 = 100\ \mu F$

$C_9 = 100\ \mu F$

$V.R_2 = 100k$

SP = 16 ohms speaker

U = LM386

C_5 is a coupling capacitor capable of receiving more than one signals (mixing). It also reduces the ripples from different input signals that it receives. V.R_2 is the master volume control; it is used to control the volume of the overall inputs either from pre-amplification stage or from VCD players. It is also used to fine tone the sounds from different inputs. C_7 is a bypass capacitor as in pre-amp stage. C_8 is gain capacitor, used to adjust or set the gain of the IC. C_6 is filtering capacitor, used to filter unwanted sounds and stabilize the output sound. C_9 both serves as filtering and coupling capacitor, SP is a *16 ohms* speaker which is the load. With this, the chip can deliver an unclipped peak-to-peak output signal that is about *80%* of the dc supply.

3. Results and Discussion

The results and discussion for an audio mixer using LM386N-I, IC are given below.

3.1 Connection Layout and Mode of Operation

The connection layout is given in fig. 5 for easy analysis of the mode of operation of the multi-input audio-mixer.

From the circuit diagram, the output from the mic pre-amp stage is fed into the power amplifier by the means of coupling capacitor C_4 and $V.R_3$ is the volume control of the pre-amplification output signal. It regulates the output signal for easy amplification by the power amplifier. The microphone has input impedance of about *600 ohms*. The sound signal of the mic is being filtered by the capacitor C_1, and its frequency is controlled by the variable resistor $V.R_1$ which is linked to the pre-amplification stage by the coupling capacitor C_2, R_2 and R_3 provide a quiescent point for the sound signal amplification by the transistor Q_1. There are other inputs but these inputs are fed to the power amplifier directly circumventing the pre-amplification unit. They are linked to the power amplifier by the means of the coupling capacitors C_5 and C_{11} for the audition and the program sections of the system. These inputs have variable resistors or volume controls that controls their volume. Diodes D_6 and D_7 are the output level indicators for the program and audition sections respectively. The audition part of the system is where most of the inputs are located. The operator uses the headphone to listen to the output of the audition part of the audio mixer before feeding it to the program part of the system for quality output. The output of the audio mixer is connected to the STL (Studio Transmitter Link) as in the case of the broadcasting studios. While in the case of the recording studio it shares the same input.

From fig. 5, the simplicity of the link between the audition output and the program output is done by tapping a cable or wire from the positive part of the *DVD* inputs in the audition part to the positive part of the input in the program part. Some of the circuit components not mentioned above is given below. It should be noted that both the audition unit and the program unit have the same value of component.

$R_5 = 4.7\ K$

$R_6 = 4.7\ K$

$VR_3 = 100\ K$

$VR_4 = 100\ K$

$C_{12} = 330\ \mu F$

D_6 = Yellow light emitting diode (LED)

This system operates in the audio frequency range *20 Hz – 20 KHz*. The entire circuit element is assembled in a perforated circuit board. The technique involves circuit mapping and component installation technique to achieve high level/optimal performance. The IC sockets which enables the ICs to be replaced or changed easily and fast are used. All components are placed such that they are all at $90\,^0$ from the plane of the project board.

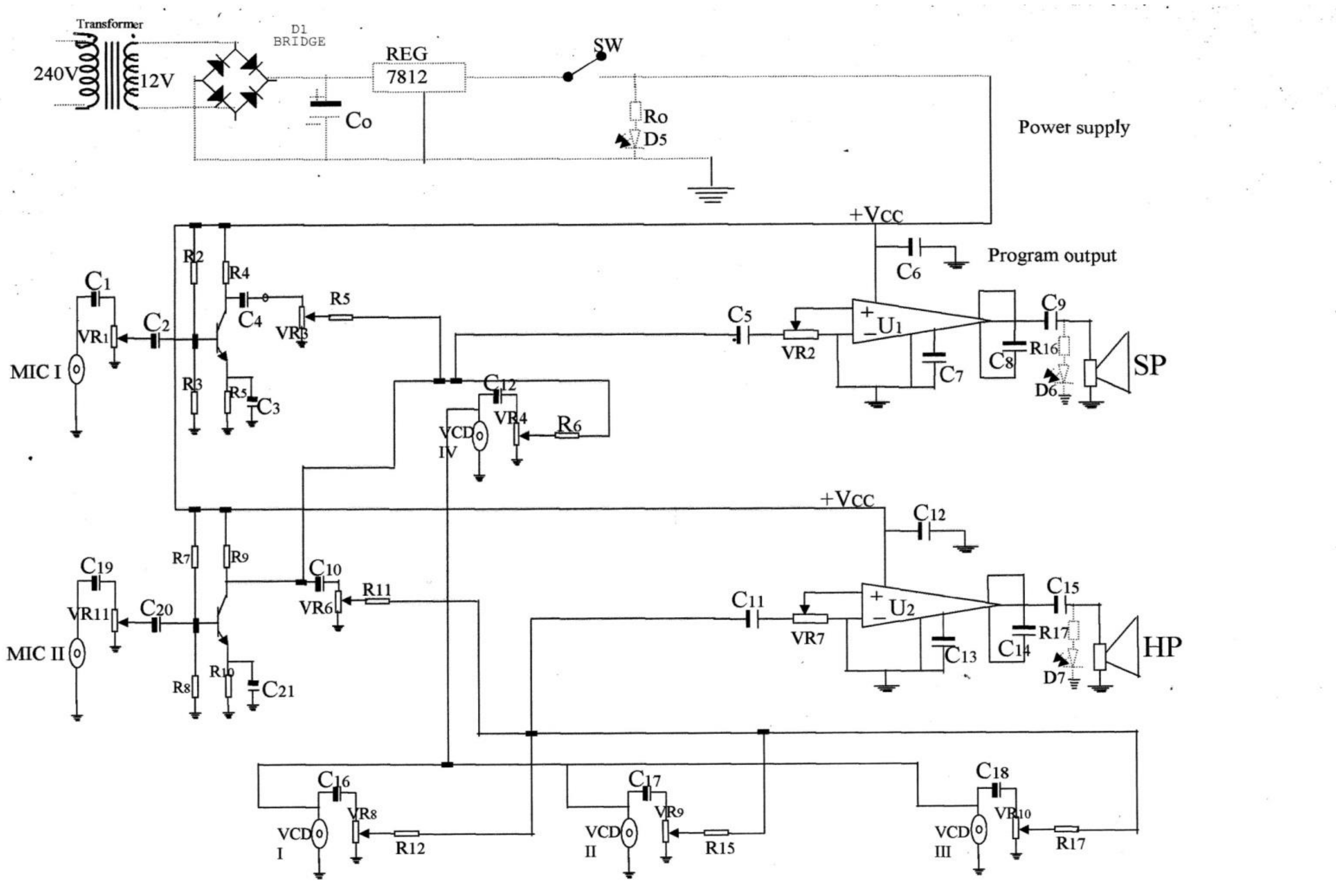

Fig. 5.0 Complete circuit diagram of multi-input audio mixer (Courtesy of Ezihe , 2010)

3.2Results

T_A = 25 °C

Operating Temperature = 0 – 70 °C

Parameter	Conditions	Min Value	Typ Value	Max Value	Units
Operating supply voltage (V_s) M360N-1		*4*		*12*	*V*
Quiescent current (I_q) quiescent	V_s = 6V, Vin = 0		*4*	*8*	*mA*
Output power (point) LM386N-1	V_s = 6V, Vin = 0	*500*	*700*		*mW*
Voltage gain (A_v)	V_s = 9V, f = 1kHz 10µF Pin 1-8	*26*		*46*	*dB*
Bandwidth (*BW*)	V_s = 6V, pins 1 & 8 open	*300*			*KHz*
Total Harmonic Distortion (*THD*)	V_s = 6V, f = 1 kHz, C bybass = 10µ pins 1 & 8 open	*0.2*			*%*
Power Supply Rejection Ratio (PSRR)	V_s = 6V, f = 1 kHz, C bybass = 10µ pins 1 & 8 open. Referred to output	*50*			*dB*
Input resistance (R_{in}) Input bias current (I_{Bias})	V_s = 6V, pins 2 & 3 open	*50, 250*			*kΩ, nA*

(www. National.com)

3.3 Discussion

All voltages were measured with respect to the ground. Absolute maximum ratings indicate limits beyond which damage to the device may occur. Operating ratings indicate conditions for which the device is functional, but do not guarantee specific performance limits. The typical value is a good indication of the device performance.

The supply voltage is *12 V* beyond which the system might start malfunctioning. The quiescent current has a typical value of *4 mA* and a maximum value of *8 mA*. The output power (typical value) of the system is about *700 mW* and the voltage gain rage is *26-46 dB* which gives the system a good sound production. The input resistance is *50 Ω* and input bias current is about *250 nA*. The frequency range of the system is *20 Hz* to *20 kHz* (audio frequency) and the efficiency of the system is moderate for mixing console. The noise filtration was achieved using *1000 μF* filtering capacitor, C_6.

The reliability of the project has been proved to be good owing to the fact that the materials used in the work are of high quality. The pre-amp stage was designed with a low noise transistor (*BC547*) and a low noise Op amp (*LM386*) in the power amplifier stage. This drastically reduced distortion. Each stage of the work was carefully designed such that it could be detached from one another. This makes replacement easy, for example, the ICs were fixed with IC sockets.

The potentiometers or faders are of high quality and are very flexible to turn around. This was done because the faders will control the signal output level and would also be constantly varied by the operator. The ability of the device to last under active operation is called durability. The device (mixer), as designed would work actively for *12 hrs* and above per a day. This was achieved with a low power consumption and low distortion operational amplifier (*LM386*). The graph of quiescent supply current (I_q) against supply voltage (V_s) increases

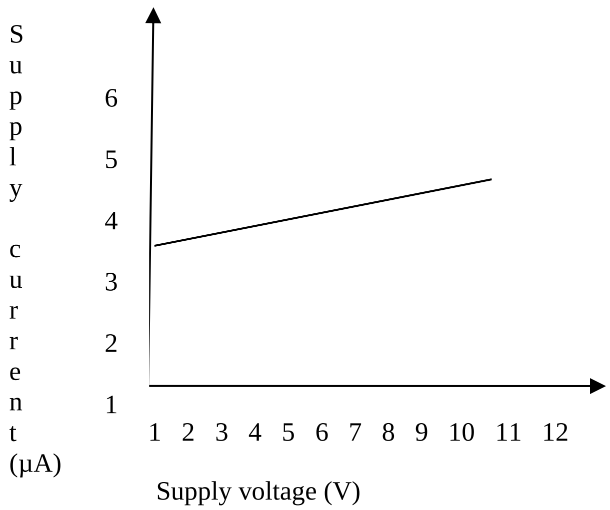

Fig. 6.0 Graph of quiescent supply current versus supply voltage

gradually which implies little variation. Results taken in the Physics lab., Federal University of Technology, Owerri, Nigeria with a GW Instek model *GOs-620* oscilloscope showed that the mixer amplitude, period and frequency varied with the loudness of the inputs (microphones and DVDs). The graph of quiescent supply current against supply voltage is given in Fig. 6.

The comparison of input and output showing clipping at the V_{max} is shown in Fig. 7.0. The input voltage is the normal sine wave while the output voltage is the resultant signal for fundamental signals and the overtones. This is known as modified sine wave.

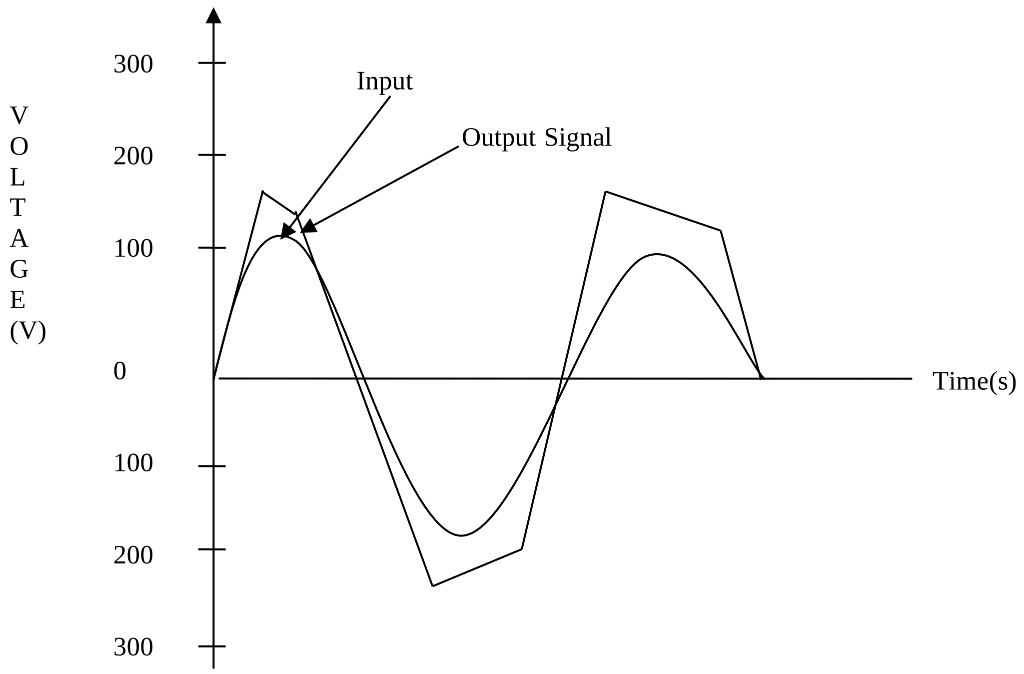

Fig. 7.0 A typical input and output signals showing clipping V_{max}

4.0 Conclusion

An inexpensive multi-input audio mixer has been designed and constructed. A simple approach of circuit mapping and component installation were used to construct the mixer. The audio mixer was constructed from the power supply section, pre-amplifier section and power amplifier section. The audio mixer gave low distortions and improved performance. Due to exorbitant prices, difficulty in operation and high cost of maintenance, the existing mixers are not readily available to average sound engineers. These challenges necessitate this work focused on design and construction of a moderate, easy to operate, light weight, inexpensive, reliable and durable, audio console (mixer). This mixer could be used by disc jockeys (DJs), small recording studio, presentations, stage performance, etc.

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