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AN OPAMP BASED 100W TRIPLE INPUT COMPLEMENTARY AUDIO MIXER AMPLIFIER WITH INDEPENDENT TONE CONTROL

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ABSTRACT

A triple input complementary audio amplifier mixer with independent tone control was constructed. The construction was carried out using opamps. The circuit was constructed such that each of the three inputs has its tone control. At the output stage, the power resistors 0.47Ω (5W) were used to maintain a stable bias and introduce some local feedback. The output voltage was measured and recorded at various frequencies using the oscilloscope. The frequency variation was carried out on the signal generator and the output voltage read from the oscilloscope with a constant input voltage of 0.2V. The frequency response of the amplifier was plotted - voltage gain A_v(dB) against the frequency f(kHz). The bandwidth and roll-off were obtained from this curve as 19.9KHz and 1.839dB/KHz respectively. Also, the voltage, current and power gains were calculated as 13.63dB, 23.52dB, and 19.04dB respectively. The efficiency was found to be 62.59%.

KEYWORDS: *Triple Input Complimentary Amplifier*

1.0 INTRODUCTION

Amplifiers are electronic systems that accept small input signal which (may be voltage, current power) and deliver a large output signal. (Greme, 1973). Mixing systems are generally required in acoustically impaired rooms such as conference or council halls or even large lecture theatres where several microphones must be used without external control system available.(Moson,2007). To achieve a maximum volume level, a mixing system capable of controlling several microphone volumes simultaneously must be installed. Mixing systems do not only combine all audio signals in one unit, they also control externally one input unit to another. These amplifiers are designed primarily to provide large amount of power to the loads, typically a few watts to tens of Watt. (Boylestad and Nasgelsky, 2003). They are more commonly used in public address systems, stereo system, etc.

Mixers can be categorized into passive and active mixers. Passive mixers are basically load isolated amplifier circuits used in the summing mode. Such circuits suffer from crosstalk which means that audio signals from cassette deck 2 although attenuated slightly, will find its way into the audio from cassette deck 1and vice versa. This goes to the central processor. (Smith, 2005) while Active mixers comprises an active mixer, which uses operational amplifier (OA) at its input and are generally called virtual earth preamplifiers. A typical OA µ741 has the following features - Very high input impedance, $Z_{in} \simeq 1.5M\Omega$, open loop gain Av $\simeq 2 \times 10^5$, very low output impedance $Z_{out} \simeq 500\Omega$, constant gain bandwidth GBN $\simeq 10^6$, slew Rate of $\simeq$ 0.5µv/nS, CMRR $\simeq$ 90dB, I_{offset} ~ 200nA and V_{offset} ~ 5mV

Even though such circuits suffer signal phase inversion, tendencies of crosstalk are negligible. This is particularly useful in mixers with many busses Here, the RMS voltage coming out of the mixer is the same as the sum of all its inputs (Smith, 2005).

2.0 Mixer Amplifier Circuits

There are basically four types of mixer circuits. These include:

i. Single – ended (SE)
ii. Single-balanced (SB)
iii. Double-balance (DB)
iv. Double Double-balanced (DDB)

Each has its own set of performance trade offs that must be considered to optimize system performance.

2.1 Single-Ended Mixers

These are the simple types using only diodes. All the ports are electrically the same, being only separated by filters that provide interport isolation. The bandwidths of the filters must not overlap if high isolation is required (Migaw, 2006).

2.2 Single-Balanced Mixers

These are composed of two single-ended mixers. A balun balances the diodes and interfaces them with the unbalanced LO input. The balun maintains precise phase angle with respect to ground ($\pm 90^0$) (Migaw, 2006). If the I/V (current-voltage) curves match with each other, and the parasitic reactances of all the diodes match, the diodes form a voltage divider causing a virtual ground to appear at the junction between the diodes. A virtual ground is anode having 90^0 phase angle with respect to ground. The virtual ground nulls out the LO voltage and keeps it from appearing at the ports, thus isolating the load port from other ports (Migaw, 2006).

2.3 Double-Balanced Mixers

These are composed of two SB mixers either as ring or star (cross) DB mixers. DB mixers are so termed because they use two baluns, whereas SB mixers use only one. Signal isolation in DB mixers is achieved in the same way as it is in SB mixers, except that the right port balun causes the LO-generated voltage appearing at the right port to equal the difference between the small voltages appearing at junctions. Ideally these LO-generated voltages are nulled out as virtual grounds, but nonidealities in balun balance and diode match allow them to appear. The LO-generated voltage appearing at I-port is sum of the small voltages at the junctions (Migaw, 2006).

2.4 Double Double-Balanced (Triple Balance) Mixers

These are formed by combining two-star or two-ring DB mixers. These two methods yield identical circuits suggesting that a duality exist between ring and star DB mixers. They are, electrically identical. Triple-balanced mixers usually offer greater dynamic range. Better IM suppression, interport isolation and broader I-port bandwidth than DB mixers although at the expense of higher LO power requirement and greater cost for four diodes and more labor necessary to match eight diodes instead of only four (Migaw, 2006).

2.6 Stability Factor(S)

This expresses the rate of change of collector current I_C with respect to the leakage current I_{CO} holding I_B constant. This is written as (Philip, 1999).

$$S = \frac{\delta I_C}{\delta I_{CO}} = \frac{\delta I_C}{\delta I_{CO}} \beta I_B \left(V_{CE}\ Const \right)$$

Thermal stability is affected by the biasing current of the transistor.

2.7 Transistor Dissipation

The power handling capability for a given transistor depends on the maximum temperature at which the junction of the device is permitted to operate and the actual ambient temperature expected in operation. The amount of power that may be safely dissipated in a transistor is given as (Philip, 1999).

$$P_D = \frac{T_{CB} - T_A}{\theta_{CB-A}}$$

where T_{CB} is the collector to base junction temperature, T_A the ambient temperature, θ_{CB-A} the thermal resistance from junction to air and T_C the approximate case temperature. This implies that heat must be dissipated to air through two series paths, from junction to case and case to air (Philip, 1999).

3.0 The Opamp Based Triple Input Complementary Audio Amplifier Mixer

This equipment is constructed with a capacity of handling 100W. The structure is made of two stages which include - viz the pre-amplification stage and power amplification stage.

3.1 The Pre-Amplification Stage

This stage consists of three input stages and one final pre-amplification stage. The three input signals are first pre-amplified and mixed together to give one single output. This single output is further pre-amplified in the final stage of pre-amplification. The output of the final stage of pre-amplification goes into the power amplifier as input. Each pre-amplifier consist of the input stage, amplification stage and independent tone control.

Signal from a microphone is fed into the circuit. The capacitor filtered out dc signal (Noise) contain in the input signal by blocking the dc signal. The resistor provides a low potential for ac signal and high potential for dc signal thereby grounding the dc signal.

This employs a negative feedback configuration of an operational amplifier (op-amp) using its inverting input. The 1kΩ resistor is the load resistor while 100kΩ is the feedback resistor, the capacitor 10µf is the coupling capacitor. The voltage gain of the amplifier is given as.

$$A_v = \frac{V_o}{V_i} = -\frac{R_f}{R_{in}} = \frac{100k}{1k} = -100$$

TABLE 1 Characteristics of TLO82ACP IC

Gain Bandwidth product	3MHZ
Slew Rate	13V/µs
Output Voltage swing	± 13.5V
Input offset voltage	± 3mV
Differential input voltage	± 30V
Supply voltage range	± 3.5V to ± 18V
SDQ	D
Test Conditions	V_s = ± 15V

3.1.3 Tone Control

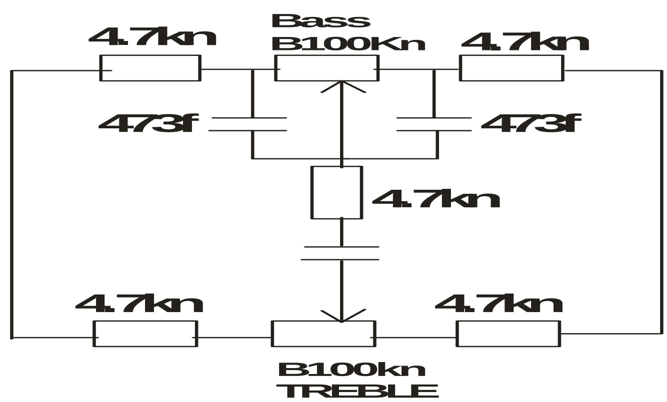


Fig 1 Independent Tone Control of Pre-amplifier circuit

This stage fine tunes the input signal using the action of the bass and treble. The bass filters out low frequencies while the treble filters high frequencies.

3.2 The Power Amplification Stage

The power amplification stage consists of three stages which include;
(i) input stage (ii) amplification stage (iii) output stage

3.2.1 Input Stage

This stage consists of diodes, resistors, capacitors and A720 transistors.

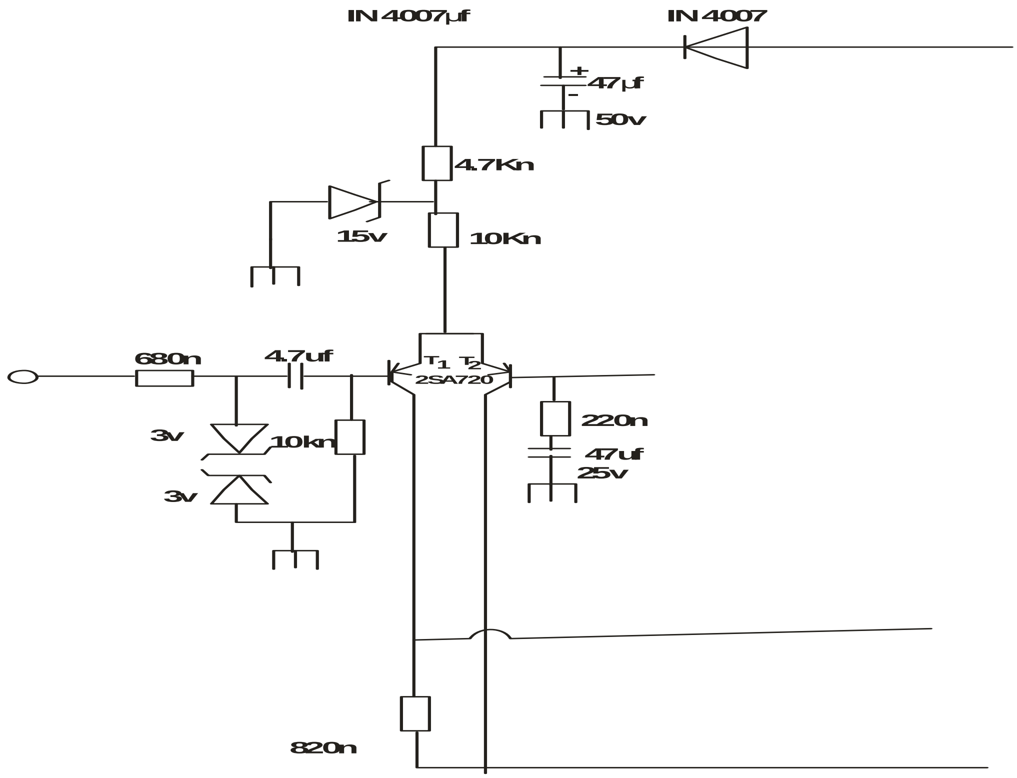
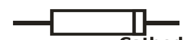


Fig 2 Input stage of power amplifier

The output from the final stage of pre-amplification is fed into the final stage of power amplifier circuit as a sinusoidal wave input. The capacitor acts as a blocking capacitor which filters out dc noise. It is chosen because it has a very small reactance to the frequency of amplification. 3V diodes and 10k resistor balances excess signal by ensuring that only the required input signal is fed into the amplification stage. The resistor 4.7kΩ and 220Ω coupled with the capacitors 47µf (50V) and 47µf (25V) serve as potential divider and prevents undesirable feedback of the amplified signal from the differential arrangement of T_1 and T_2. They also stabilize excessive temperature. The 15V zener diode through the 10kΩ resistor serves as a regulator which ensures that approximately +5V is going into the emitter of T_1 and T_2. The diode IN4007 ensures that the +27 V_{CC} is forward biased (positive polarity).

T_1 and T_2 arranged in a differential pair acts as the input stage. The operation of the differential pair is known as single-ended. The other input is connected to the ground. It uses two separate voltage supplies. They are chosen at the input stage because differential amplifiers have a very large current gain and are more stable than the Darlington pairs. The current of the input stage operates in a current mode due to this combinations.

TABLE 2 Characteristics of Active Elements

Element	Description and Application	Voltage (Volts)	Current Amperes	Power Watt	Frequency MHZ	Structure/Figure
2SA720	Universal, Silicon Positive Transistor	80	0.5	0.625	200	 B C E
3V-Z-Diode	Zener Diode	3.3, 20%		1.5		Anode  Cathode
15V-Z-Diode	Zener Diode	15, 20%		1.5		Anode  Cathode
IN4007	Silicon Diode (Rectifier), General Purpose Type	1000	1			Anode  Cathode

3.2.2 Amplification Stage

The second stage of amplification occurs with T_3, T_4 and T_5 in a class B arrangement which is responsible for the large proportion of the overall gain of the circuit. This type of arrangement uses transistors having complementary symmetry in the emitter follower configuration. NPN and the other PNP, having identical input and output characteristics. Both transistors have equal biasing resistors and biased with the same voltage.

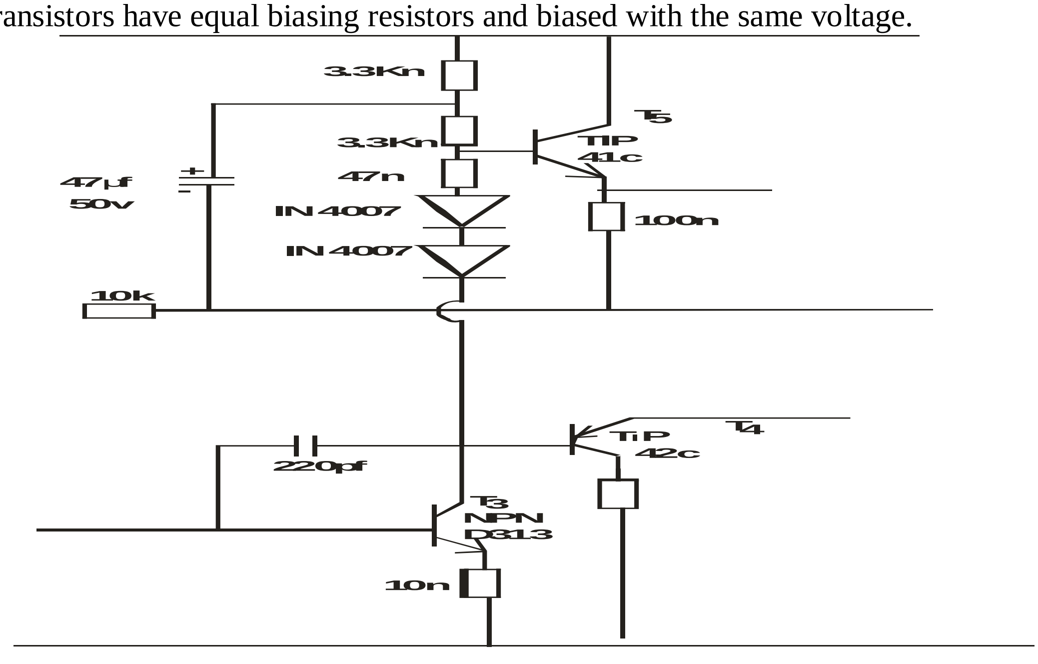
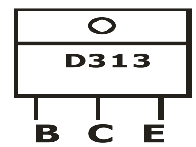
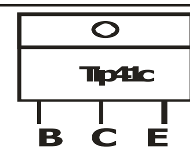
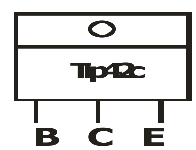


Figure 3 The amplification stage of power amplifier

The transistor T_3 (D3*13*) at the initial stage of the complementary symmetry improves the gain of the signal going into transistor T_5 (Tip 42C) and is biased by the resistor (820Ω) from the output of T_1 collector. The T_4 (Tip 41C) is biased by carefully selected resistor and capacitor to give the base current.

T_5 resistor (Tip 42C) is directly coupled from T_3 after the gain has been increased to match that of T_4. This is because it is fed from one of the collector of the differential pair. The two diodes (IN4007) are used to ensure that the polarity of base voltage of drivers is positive for the NPN (D313) transistor and negative for PNP (Tip 42C) transistor. While the 3.3kΩ serves as a biasing resistor for T_4. The signal at this stage has been amplified to a reasonable amount. The transistors at the driver stage each have a current gain of 40 and power of 40W. The output signal of each of the driver transistor is half of the input signal, the NPN (D313) conducts for the positive half of the input signal while the PNP (Tip 41C) is off and for the negative half D313 is off while (Tip 41C)conducts.

Table 3 Characteristic of transistors used.

Element	Description and Application	Voltage (Volts)	Current Amperes	Power Watt	Frequency MHZ	Structure/Figure
2SD313	Silicon Negative Transistor. For Audio Frequencies, Switching and power Stages	60	3	30	8	
Tip41c	Silicon Negative Transistor. For Audio Frequency application at power Stages	115	6	65	>3	
Tip42c	Silicon positive Transistor. For Audio Frequency application at power Stages	115	6	65	>3	

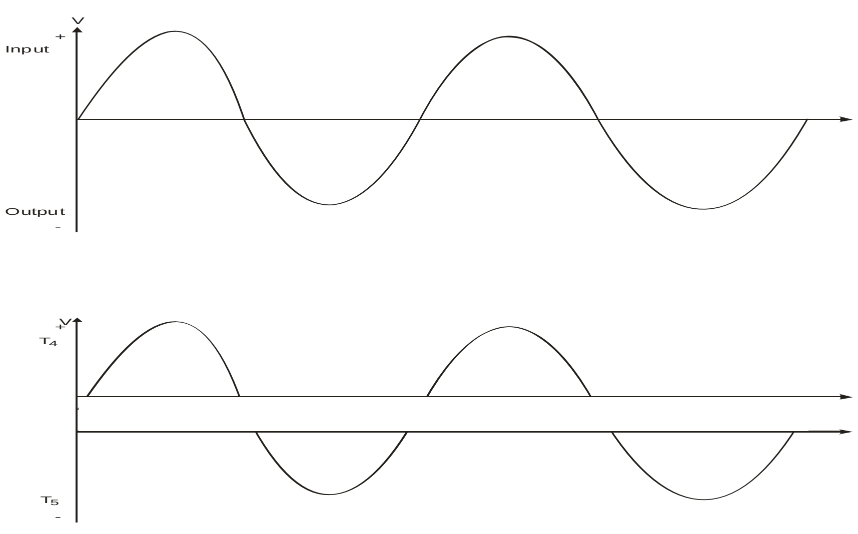


Fig 4. Waveform of T_4 and T_5

Each of these is now sent to the output stage which is the final stage of amplification.

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3.2.3 The Output Stage

The output stage is a simple circuit made up of two power transistors (2N3055) and two power resistors.

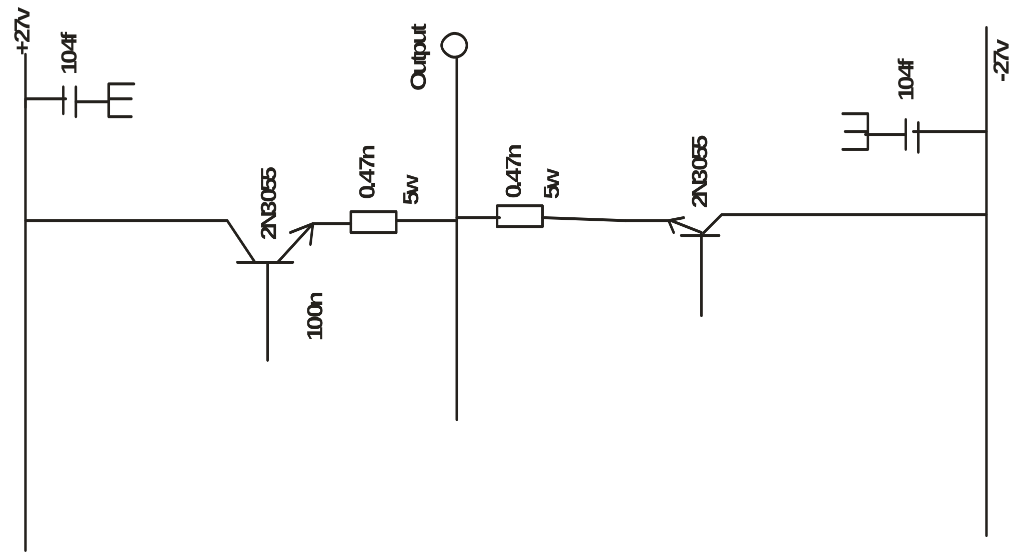


Figure 5 The output stage of power amplifier.

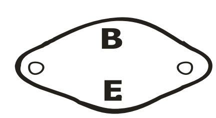
The 0.47Ω (5W) resistors are appropriately selected to help maintain a stable biased and also introduce some local feedback.

The output power of these power transistors is fed with half wave form of input signal which is equally amplified and summed up at the output. Due to the push-pull arrangement of the driver stage, the maximum power of each of the power transistor is halved.

$P_o = ½\ 115W = 57.5W$

Total output with some losses inclusive, was measured as 100W

TABLE 3.4: Characteristics of a Transistor

Element	Description and Application	Voltage (Volts)	Current Amperes	Power Watt	Frequency MHZ	Structure/Figure
2N3055	Silicon Negative Transistor. For Audio Frequency application at Switching stages and power Stages	100	15	115	>2,5	

3.3 KPKM4080 MIXER

The Kustom KPM4080 is an easy-to-operate powered mixer that provides dependable sound reinforcement and real value. It features 80 watts of output power and four channels with balance XLR and line level inputs. Tone is handled by a 3-band master equalizer plus a separate tone control for each channel. (Cady, 2004).

4.0 Results of Amplifier Measurement

TABLE 6. Results of amplifier Measurement at various frequencies with V_{in} at 0.2V

S/NO	$F_{(Hz)}$	$F_{(KHz)}$	$V_{out(volts)}$	A_v	A_v(dB)
1	20.0	0.020	0.4	2.00	6.021
2	25.0	0.025	0.50	2.50	7.958
3	30.0	0.030	0.60	3.00	9.542
4	35.0	0.035	0.72	3.60	11.26
5	40.0	0.040	0.84	4.20	12.464
6	60.0	0.060	0.90	4.50	13.064
7	80.0	0.080	0.93	4.65	13.349
8	110.0	0.110	1.00	5.00	13.979
9	280.0	0.280	1.10	5.50	14.807
10	850.0	0.850	1.20	6.00	15.563
11	1000.0	1.000	1.20	6.00	15.563
12	1500.0	1.500	1.20	6.00	15.563
13	2000.0	2.000	1.20	6.00	15.563
14	3200.00	3.200	1.20	6.00	15.563
15	5000.0	5.000	1.20	6.00	15.563
16	7000.0	7.000	1.20	6.00	15.563
17	7500.0	7.500	1.20	6.00	15.563
18	8000.0	8.000	1.20	6.00	15.563
19	8800.0	8.800	1.20	6.00	15.563
20	9500.0	9.500	1.20	6.00	15.563
21	12000.0	12.000	1.20	6.00	15.563
22	13000.0	13.000	1.20	6.00	15.563
23	15000.0	15.000	1.20	6.00	15.563
24	19000.0	19.000	1.20	6.00	15.563
25	21000.0	21.000	0.65	3.25	10.237
26	23000.0	23.000	0.52	2.60	8.299
27	25000.0	25.000	0.41	2.09	6.235
28	27000.0	27.000	0.32	1.60	4.082

From the frequency response curve, the 3dB points F_{cl} and F_{ch} are 0.2KHZ and 20.1KHZ respectively which is known as half power points.
The bandwidth which is calculated from the relation as obtained from:.
BW = $f_{ch} - f_{cl}$ = 20.1-0.2 = 19.9KHZ
Roll-off which is the decrease in gain Av with frequency can be obtained from the slope.

$$Slope = \frac{A_V(dB)}{f(kHz)} = \frac{12.7-7.0}{24.1-21.0} = 1.8387\ dB/kHz$$

4.1.1 The Voltage gain

The mean voltage gain from Table 4 is 4.803. The voltage gain in dB can be calculated from

$$A_V(dB) = 20\log_{10}\frac{V_{out}}{V_{in}} = 20\log_{10} A_V = 20\log_{10} 4.803 = 13.631\,dB$$

4.1.2 The Current gain

The maximum collector current I_C of the output transistor was measured to be 15A. The dc current drawn in each of the differential pair is the bias current I_{cq}. For each transistor that made up the differential pair 1_{cq} = 0.5A. For a differential pair, The current gain in dB is given as:

$$A_i(dB) = 20\log_{10}\frac{I_{out}}{I_{in}} = 20\log_{10} A_i = 20\log_{10} 15 = 23.522\,dB$$

4.1.3 Power gain in the Differential Pair

For the differential pair, the power input of each transistor = 0.625W

$P_{total} = P_{T1} + P_{T2}$ = 0.625 + 0.625 = 1.25W

3.0 Discussion and Summary

A triple input complementary Audio Amplifier mixer with independent tone was constructed. The pre-amplification and amplification stages were the stages of this construction. The pre-amplification stage which consist of three input stages and one final pre-amplification stage is so arranged to allow the three input signal to be first mixed and the single output further pre-amplifie r before being fed into the power amplifier circuit.This consist of a capacitor which filtered out dc signal as noise and the load resistor and feedback resistor which allow for the gain of this stage. The amplification stage which consist of the input, amplification and output stages were arranged in this manner for better output. The input stage allows the sinusoidal wave signal to be fed to it and the resistors in this stage are of acceptable values to prevent. The differential pair arrangement at the input stage ensures a very large current gain and are stable too. In the amplification stage, the transistor T_3 (D313) improves the gain going into one of the transistor T_5 (Tip 42C). At the output stage, the power resistors 0.47Ω (5W) are used to help maintain a stable bias and introduce some local feedback. The output voltage was measured at various frequencies using the oscilloscope. The frequency variation was carried out on the signal generator and the output voltage read from the oscilloscope with a constant input voltage of 0.2V. The frequency response of the amplifier was plotted - voltage gain A_v(dB) against the frequency f(kHz). The bandwidth and the roll-off were obtained from this curve as 19.9KHz and 1.839dB/KHz respectively. Also, the voltage gain, current gain and power gain were calculated and were obtained to be 13.63dB, 23.52dB, and 19.04dB respectively. The efficiency was found to be 62.59%.

A triple input complementary audio amplifier mixer with independent tone control was constructed. The construction was carried out in two stages which include;

i. Pre-amplification stage
ii. Amplification stage

The pre-amplification stage was constructed using elements such as the resistors, capacitors and operational amplifier. The arrangement also consist of tone control for each of three input designed.

The amplification stage consist of elements such as the resistors, diodes, capacitors and transistor. These elements work together to ensure that the input signal is amplified at the output of the power amplifier.

Output voltages were obtained by varying frequency from the constructed audio amplifier mixer using constant input voltage. The amplifier gain A_v and the gain in decibel A_v(dB) were further calculated.

Also the bandwidth and the Roll-off were calculated from the frequency response curve which was plotted using the gain of amplifier A_v(dB) against the frequencies varied (KHz). The results were found to be 19.9KHz for bandwidth and 1.839 dB/KHz for Roll-off.

The voltage gain, current gain and power were determined and were found to be 13.63dBm 23.52dB, and 19.04dB respectively. The efficiency was also determined and was found to be 62.59%.

The efficiency of this work which is 62.59% did not meet the standard efficiency which is 78.5% due limitation and some losses of heat and over driving of the driver stage transistor.

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