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Implementation of Efficient Class B Large Signal Amplifier using Multisim

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Abstract**—** Power amplifiers are used as the last stage of a multistage amplifier and are used to amplify aweak input signal to drive the loudspeaker or an output device. The Class B Power amplifiers are expected to achieve very good performance when compared toother classes of Power amplifiers. In these amplifiers,the distortion of the signal can be significantly mitigated. In this paper, we propose a circuit which reduces the cross over distortion. The proposed circuit employs complementary transistors& an operational amplifier configured inthe negative feedback.TheMultisim simulation of the proposed high performance Class B Complementary Symmetry Push Pull amplifier shows that there is a significant decrease in the cross over distortion and an increase in the conversion efficiency of the amplifier up to 87%.

Index Terms**—***Power Amplifier, complementary symmetry push pull Amplifier, Cross over Distortion, Efficiency, negative feedback.*

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I. INTRODUCTION

The power efficiency of an amplifier, which relates the amount of DC power input converted to useful AC output power, enhances starting from class Aoperation and ending at class D operation. In normal conditions, we observe that a class Alarge signal amplifier, with dc voltage biased at 50% of the signal voltage level, utilizes a considerable amount of power to maintain proper transistor bias, even when no signal voltage is applied. As a result the output signal is distorted for small values of inputs, when a small AC inputpower is applied to the load [1], this is in fact, the extreme class Alarge signal amplifier. The conversion efficiency, which exists for greatest value of the output voltage and current variation,is only 0.25 or 25% in a directly coupled load and 0.5 or 50% for a transformer coupled circuit. The Class B operation provides a greater conversion efficiency which is 78.5%, when compared to Class B, the Class D large signal amplifier is much better andgives a better conversionefficiency of 90%, whereas theconversion efficiency of class AB amplifier, which is the combination of class A and class Branges from 25% to 78.5% [2,3]. The class B large signal amplifier uses a complementary symmetry push pull circuit consisting of two transistors, one of which is NPN and the other is PNP, they are used to provide signals which are equal in magnitude, but differ in a phase of 180° [4]. The transformer coupled large signal amplifiers are costly and bulky with poor frequency response, hence not widely preferred. [5].

The large signal amplifiers are classified as class A, B, C and AB configurations for analog based designs and as class D and E for switching designs based on the proportion of each input cycle, during which an amplifying device is passing current. The transistor biasing conditions determines the conduction angle of a power amplifier. When the device is biased in such a way that it conducts current for the full cycle of AC input, then the conduction angle is said to be 360°, however when the transistor conducts current only for one half cycle of the applied AC input, then conduction angle is said to be 180°. The Table1 summarizes the different classes of power amplifiers along with their efficiencies. The class C amplifier, because of large distortion is normally not used for delivering great amounts of power to the load; hence the power efficiency for it is not specified in the Table1.

The distortion plays a very important role in the proper selection of a particular class of a large signal amplifier for a particular application. The large signal amplifier is also called soas it utilizes larger portion of load line for the intended operation. The small signal amplifier basically uses small portion of the load line for its operation. The Power amplifier increases the power levels of the input signal. In order to get greater output power, it is necessary that the input signal voltage is large. This explains the reason behind using a voltage amplifierstage before the Power amplifier stage in an electronic amplifier system.

The power amplifiers do not amplify the power; they simply draw the power from the DC supply and convert that into useful AC signal power. TheAC power available at the output terminals of the power amplifier is controlled by the input signal. The power amplifier is defined as an electronic device which converts theDCinput power into useful

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ACoutput power, whose action is controlled by the input signal.

Class of operation	A	B	C	AB
Transistor Conduction angle	360°	180°	<80°	180°-360°
Power Efficiency	25%-50%	78.5%	--	50%-78.5%

Table1: The different classes of a power amplifier

As given in the Table1, the class B large signal amplifier has greater efficiency than the other classes of the power amplifiers.The Class B amplifiers only amplify half of the AC input wave cycle, thereby creating a considerable amount of harmonic distortion, but the ability to convert the DC input power to AC output power is greatly improved. The Class B amplifiers also find applications in devices operated by DC batteries, such as the transistor radios. Since the amplifying element is switched off for half the time period, hence it cannot dissipate power in that half cycle. Thus the class B has a maximum theoretical conversion efficiency of 78.5%.A single class B element is not found in practice, though it can also be used in Radio Frequency applications, where the distortion levels are less important and in this regard, the class C power amplifier is most commonly employed.

The “Push Pull” amplifier is basically a large signal amplifier having an output stage which can drive the current in both the directions through the load. The output of a typical Push Pull amplifier consists of two identical transistors, which can be either BJT or FET. Out of the two transistors, one transistor sources the current through the resistive load and the other transistor sinks the current through the resistive load. When compared to a single ended amplifier, the Push Pull amplifier is advantageous in terms of circuit performance and distortion. A single ended amplifier, irrespective of its design method, will definitely introduce some distortion due to non-linear features of the active device. In the basic operating principle of a Push Pull amplifier, the input signal which needs to be amplified is capacitively coupled andthenapplied to the respective base terminals of the two transistors, differing in phase by 180˚. The input applied to the two bases are said to be in “Push Pull” or phase opposition of 180˚.

The major advantages of push pull amplifiers are:

1) Less amount of harmonic distortion

2) Higher conversion efficiency.

3) Absence ofAC ripples.

4) Absence of signal noise.

The disadvantages are:

1) It requires two identical transistors.

2) Proper biasing has to be maintained.

The class B circuit constructed here uses a degenerative feedback path to increase the linearity range and a resistor is connected tocontrol the gain in feedback path, this will improve linearity range and definitely controlsthe gain by reducing the cross overnon lineardistortion, thedegenerative feedback is taken from the push pull amplifier circuit’s output and given to the inverting input ofamplifier circuit.

II. LITERATURE SURVEY

The complementary symmetry push pull circuit usesactive devices, such as NPN and PNP transistors or they can use NMOS and PMOS transistors, which areused for amplifying two half cycles of the AC input signal, which are then combined at the output side. Thisarrangement results in good amount of conversion efficiency, but has the demerit that, the two transistors do not conduct current until their input voltages exceeds the threshold voltage of the semiconductor device,as a result this arrangement produces a distortion popularly known as “Cross Over Distortion” which is shown in Fig.1.The distortion can be reduced by properly biasing the active device, so that the operating point is not completely in cutoff region. This approach is called Class AB operation [6].There are circuits [7], which design the hardware model of class B power amplifier using complementary transistors, such as “NPN” and “PNP” transistors, capacitors, diode and other resistance of some standard specifications. Such circuits, even thoughare efficient, but consume more power.

Amongst all the classes of the power amplifiers, the Class A large signal amplifier [8] is the most general and simplest form of power amplifier, wherein the active device are configured in Common Emitter mode of operation. The active device is biased in such a way that, always it conducts current during one complete cycle of the input signal waveform producing meager harmonic distortion and greater voltage levels at the output and the conduction angle of the transistor is 360˚.

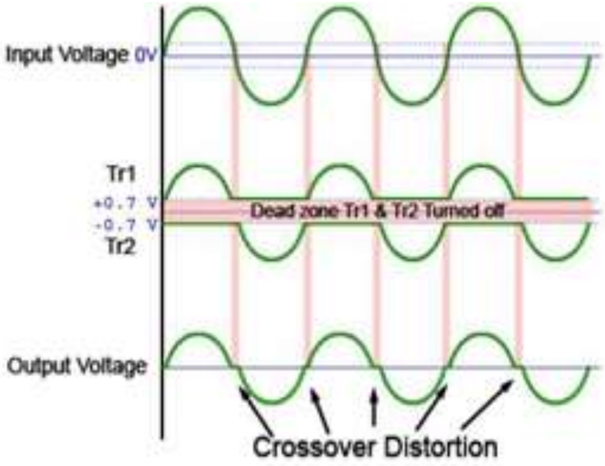

Fig.1: Cross over Distortion [8]

The Class Alarge signal amplifier configuration is considered as a good modeof operation, because of the absence of the crossover distortionin the output signal.TheClass A power amplifier find their application in low power audio frequency amplifiers as well as in radio frequency voltage amplifiers.

There are two types of classA power amplifiers, namely: direct coupled or single ended and Transformer coupled amplifiers. The single ended amplifiers have less efficiency of 25%. The active elements are forward biased full time, some current will flow through them even though there is no input signal, and this is the main reason for the inefficiency of the amplifier, because of which it is not widely used.

In a Transformer coupled amplifier, the load is coupled to the output using a transformer. By using Transformercoupling, greater amount of DC input power can be converted into AC output power, thereby increasing the conversion efficiency of the large signal amplifier by a considerable amount. The coupling transformer matches the input resistance with the output resistance of the load and is responsible for the upgraded conversion efficiency. The Transformer coupled amplifiers have many advantageslike:

1)Increased Efficiency of 50%
2) Better separation of the direct current voltages.

The disadvantages of the transformer coupled amplifier are:

1) Difficulty tofind an exactly matching transformer.
2)The transformers are bulky.
3) The cost and size of the amplifier is more.
4) Thefrequency response ofthetransformer coupled amplifier is not good.

The Class C large signalamplifier is a circuit, wherein thecurrent conduction of the bipolar junction transistor takes place for a period, which is less than 180°. The reduced angle of conduction, greatlyupgradesthe circuit efficiency to a great extent,but causes a lot ofharmonicdistortion. Due to the upgradedharmonic distortion, the Class C mode of operation is not preferred for amplifying signals in the audible range.

The Class D power amplifier provides greater efficiency, which is normally 90%, but it can be used only for pulsed operation.

The ClassAB large signal amplifier has lesser conversion efficiency than the class B amplifier, the amount of zero signal current flowing through the active device is lesser and it has lesser amount of cross over distortion. The class AB circuit is widely employed for amplifying signals in the audible range. The conduction angle of a class AB circuit is larger than that of class B amplifier, but lesser than that of the class A circuit.

III. AMPLIFIER ANALYSIS

In this paper, we mainly deal with the class B complementary-symmetry push pull power amplifier. As shown in Fig.2, in the class Bcircuit,we use two transistors, which are complementary to each other. The circuit uses one NPN transistor and one PNP transistor, which conduct current alternately in each of the half cycles of the input AC signal.
The class B complementary symmetry push pull circuit has many merits like:

1) Less power dissipation
2) Transformer less, hence simple circuit
3) Less power consumption
4) Better output AC power
5) Higher conversion efficiency
6) Absence of even harmonic terms in the AC power output.

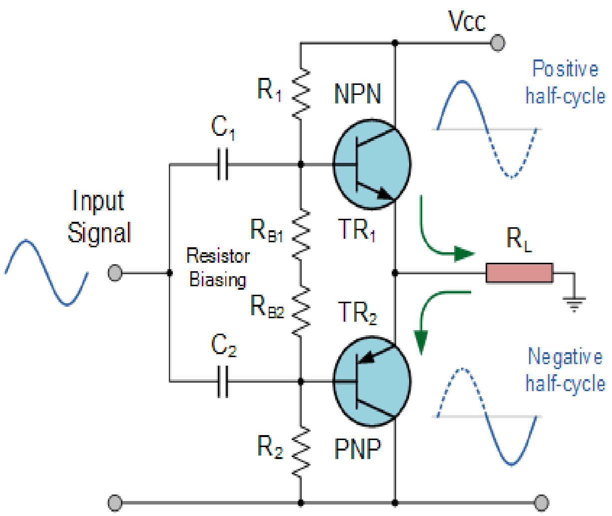

Fig.2: Circuit diagram of class B Complementary symmetry push pull amplifier with transistors [7]

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1. Design Equations:

The performance of the power amplifier is basicallyanalyzed in terms of three performance parameters namely: 1) Circuit efficiency 2) Output power delivered to the load 3) Power dissipation

The amount of the DC input power, which is converted to useful AC output power, is called as the "Circuit efficiency" or "Conversion efficiency". The amount of heat liberated in the operation of a power amplifier is called as "Power dissipation". To reduce the power dissipation "heat sinks" are used.The heat sinks are the mechanical devices, which absorb the excess amount of heat generated during the operation of a large signal amplifier.

The design equations to calculate the different performance parameters are given below:

a. Maximum circuit efficiency:

$\%\boldsymbol{\eta}= \boldsymbol{P}_{out}(\boldsymbol{ac})/P_{in}(dc)$ x 100% (1)

b. AC output power delivered to the load:

$\boldsymbol{P}_{out}(\boldsymbol{ac})_{max} = Vcc^2/R_L$(2)

c. DC input power:

$P_{in}(dc)= V_{cc}I_{dc(max.)}=2Vcc^2/\pi R_L$(3)

d. Maximum power dissipation of BJT:

$P_{D(max).} = Vcc^2/\pi^2 R_L$(4)

e. Gain with feedback:

$A_{vf}=V_o/V_s= A_v/1+A_v\beta$ (5)

f. RMS AC output power:

$P_o(ac)= v_{rms}i_{rms}$(6)

g. Power gain:

$A_P= \boldsymbol{P}_{out}/P_{in}$ (7)

The proposed circuit diagram of class B complementary symmetry Push Pull amplifier is shown in Fig.3.Thedesign uses degenerative feedback to improve the circuit performance.

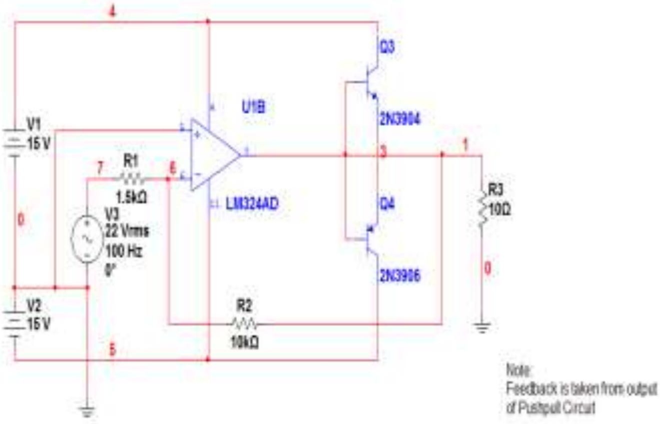

Fig.3: The proposed circuit diagram of class complementary symmetry Push Pull amplifier

The Complementary symmetry class B push pull amplifierhas a higher conversion efficiency of 78.5%, and has a distortion similar to a class Apower amplifier. To operate the class B power amplifierin sub octave bandwidth, we can change the class B push pull power amplifier by using a single ended class B power amplifier using either a low pass filter orband pass butter worth filter. A single ended class-B large signal amplifier can achieve higher power efficiency and high third order intermodulation confinement, simultaneously, if the transfer characteristics (variation of drain current with respect to Gate to Source voltage) are linear over the threshold. It is also experienced that the common drain class B large signal amplifier has very small distortion, and the distortion is much less, when compared to the common source configurations.The degenerative feedback is being used to correct the errors and reduce the cross over distortion in the output.

IV.SIMULATION RESULTS

The basic "complementary symmetry Push Pull" amplifier andthe proposed circuit output at a frequency of 100 Hz and 1 KHz is shown in Fig.4&5.The waveform shows that the proposed transistor based circuit is muchlinear, in comparison to the basic "class Bcomplementary symmetryPush Pull" amplifier. The Linearity indicates the resemblance of the output signal with respect to the input signal. By employing the degenerative feedback, we have reduced the cross over distortion significantly.
In addition to this, by increasing the conversion efficiency, we can increase the voltage gain as well.The voltage gain of the electronic amplifiers can be controlled by varying thefeedback resistor R_f. Thisrelationship between gain and efficiency is readily observed in Table given below.The Table below shows the conversion efficiency fordifferent design parameters used in the circuit. Initially, we applied 17 V as ac input voltage and 10kΩ as the feedback resistor; with this we have achieveda maximum voltage gain of 20 db

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and a maximum conversion efficiency of 87 %. Later, weapplied; an ac input voltage of 20vandconnected a resistance of 10kΩin the feedback path, together with a resistance of R_1 equal to 1.5kΩ whichin turn reduces the voltage gain and conversion efficiency of circuit. Figure 4&5 shows that, by using the class Bcomplementary symmetry pair circuit in Push pull configuration, the output conducts current for the full cycle of ac input(with a conduction angle of 360°) and a completely diminished crossover distortion using degenerative feedback connection as represented in the proposed circuit.

Ac Input Voltage	R_1	R_2	R_L	%Efficiency	A_v	A_{vf}	Max. Power Dissipation
17v	1K	10K	8Ω	87	20	0.58	4w
20v	1.5K	10K	10Ω	85	13	0.43	5w

Table 2: Results of Mathematical Analysis of design equations

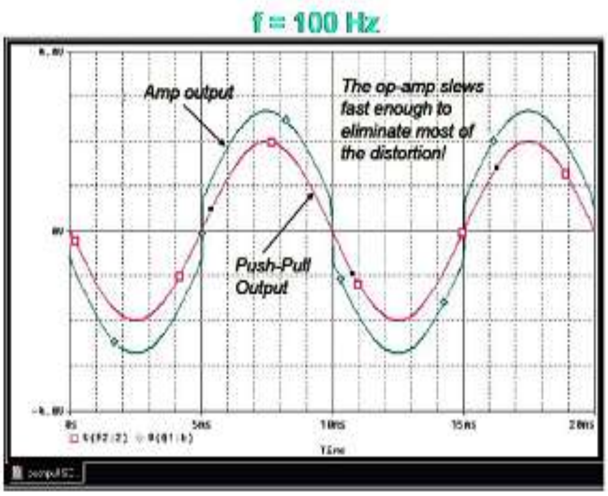

Fig.4: Output of Push Pull amplifier at 100 Hz

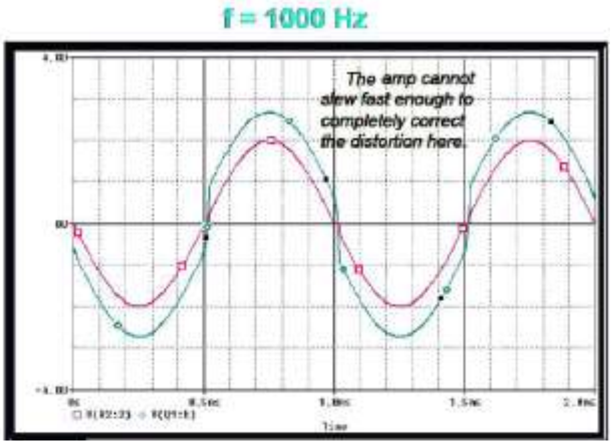

Fig.5: Output of Push Pull amplifier at 1KHz

CONCLUSIONS

The circuit performance of class B large signal amplifier has been analyzed, connected in degenerative feedback. The proposed electronic circuit has been successfully verified for different frequencies & varied circuit components. We have achieved much higher conversion efficiency of 87%. The degenerative feedback path in the respective configurationreduces the variation of output signal with respect to input signal and thereby reducing the crossover distortion in the output signal.

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