Faculty of Engineering and Technology

Electrical and Computer Engineering Department

Lab Electronics (ENEE3102)

Report of Experiment 7

"Power Amplifier"

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Chapter 1: Abstract

The aim of this experiment is to identifies the classes of the power amplifiers and distinguish between them according to their outputs. Moreover, to understand and acknowledge the design of a power amplifier using push-pull techniques, and that can be done by using an oscilloscope to observe the outputs of the different power amplifiers.

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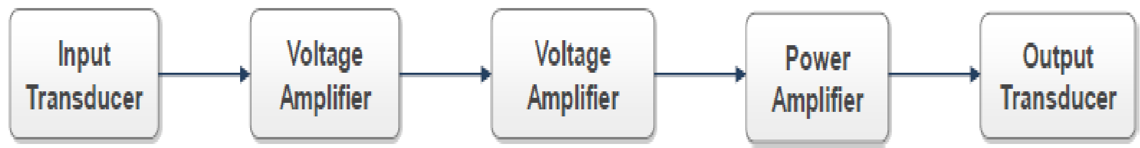
Chapter 2: Theory

A power amplifier circuit is a circuit used to deliver a high amount of power with a good efficiency. It is often the last stage of any amplifier system like Op-Amps. The Figure 1 illustrates a block diagram of a circuit using a power amplifier for audio cases.



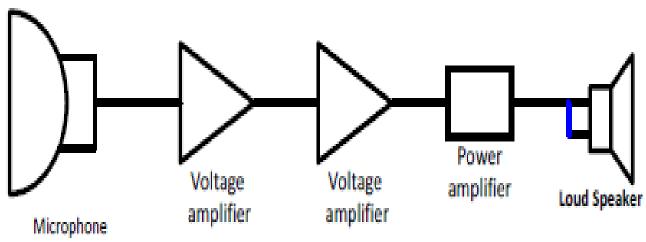


Figure 1: The Block Diagram of a Power Amplifier Using in Audio Amplifier Circuit

According to the position of the bias point, the power amplifiers have been classified to A, B, AB, C, and other classes

1) Class A:

They are the most common type of power amplifier due mainly to their simple construction (design).

The bias point of this class is in the middle of the ac load line, which justify the maximum symmetrical swing condition. In other words, the amplifier doesn't enter the cut off or the saturation region during its operation. However, this type of amplifier has the worst efficiency (which can be calculated using the formula $\eta = \frac{Pl,ac}{Pcc}$; where η is the efficiency, $P_{l,ac}$ the ac power delivered to the load, P_{cc} the power delivered from the source to the amplifier circuit) which is about 50% commonly.

Although the simplicity of this class is one of its advantages, but due to the choosing of the bias point (which meets the maximum symmetrical swing) makes the amplifier consuming the power whether there is an input signal or not, which makes the circuit needs sufficiently **Heat Sinks**.

Figure 2 illustrate the operating curve of Class A power amplifier.

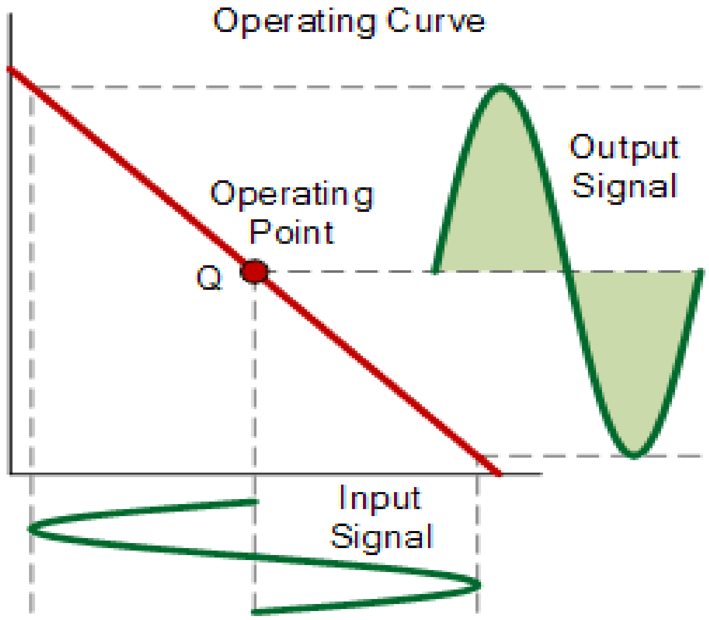


Figure 2:Operating Curve of Class A Power Amplifier

2) Class B (push-pull)

This class was designed to solve the problem of the efficiency and the heat in class A. the basic idea of the construction is to use 2 transistors (either BJT, FET, or even IGBT) everyone amplifies half of the signal. Class B is designed without using any bias sources (the input signal itself biasing the transistors). Ideally, class B just loss its linearity, but practically, there would be a cross over distortion in the output due to the location of the bias point. That problem was solved almost using the class AB.

Figure 3 illustrates the operating curve of class B (the input and the output of one of the transistors).

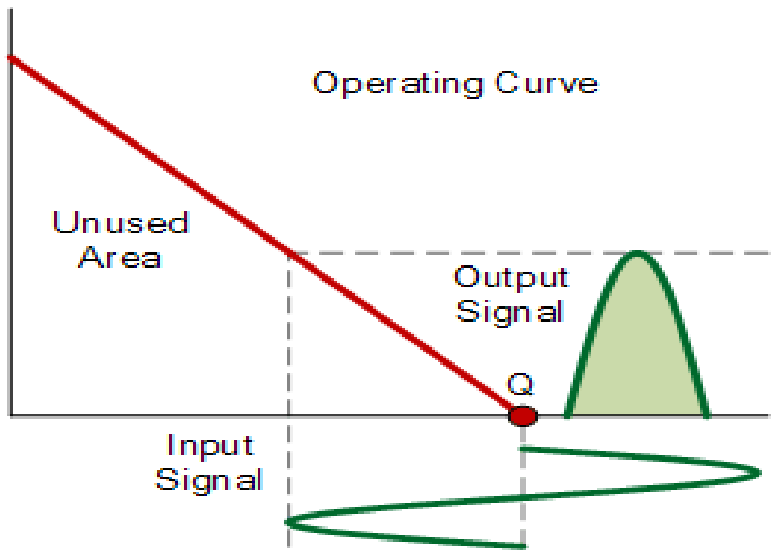


Figure 3 : Operating Curve of Class B Power Amplifier

3) Class AB

This class was designed to solve the cross over distortion problem in class B, and it was named as AB, because the class A works for 360^{o} and class B works for 180^{o}, however class AB works between them. In other words, class AB has a bias source but not like class A. Figure 4 illustrates the operating region of class AB amplifier which shows the input and the output of one of the transistors.

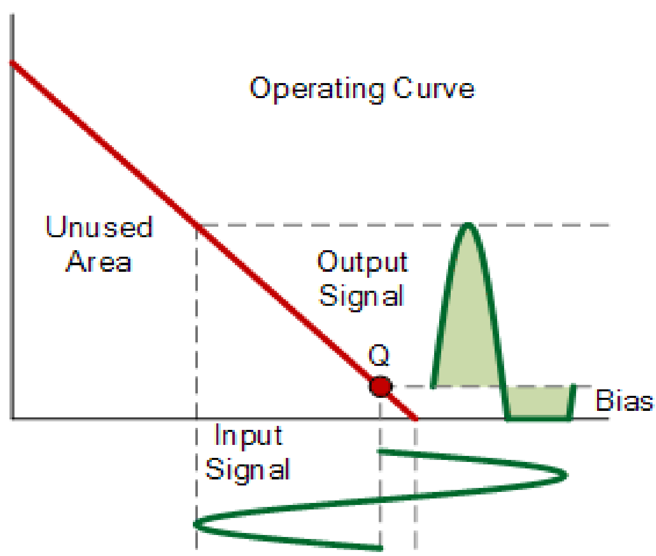


Figure 4: Operating Curve of Class AB Power Amplifier

Chapter 3 : Procedure & Data discussion

I. The Classes of Power Amplifier

1. The circuit in Figure 5 was connected

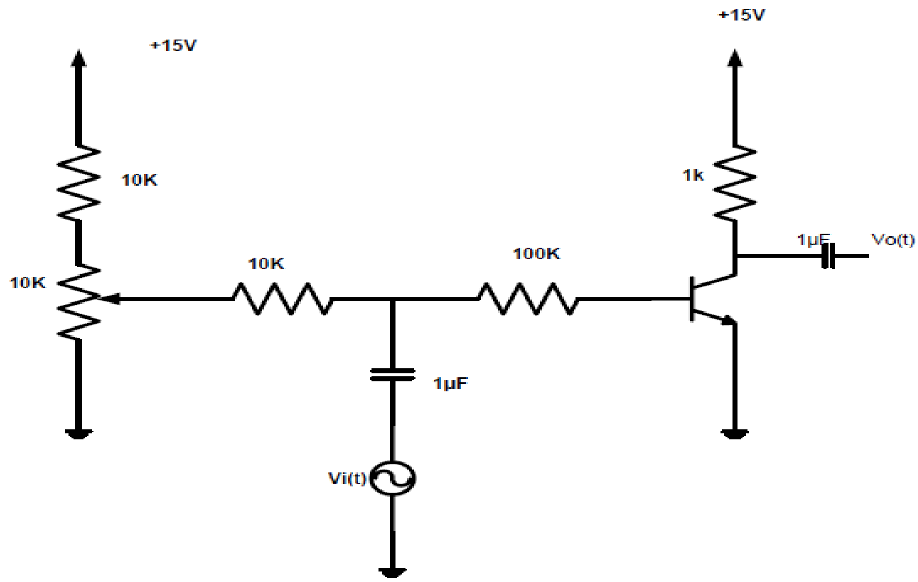


Figure 5

2. The oscilloscope was connected to the input and the output of the circuit, and the potentiometer was put at fully clockwise (the bias control was zero).
3. The output of the function generator (the input to the circuit) was increased until the Figure 6 was occurred.
4. The bias potentiometer was turned up until the output looked like Figure 7.
5. The bias potentiometer was turned up further till the output looked like Figure 8.
6. Using the signals that was used in step 4 (as illustrated in Figure 7), the output of the function generator was increased till the output looked like Figure 9.

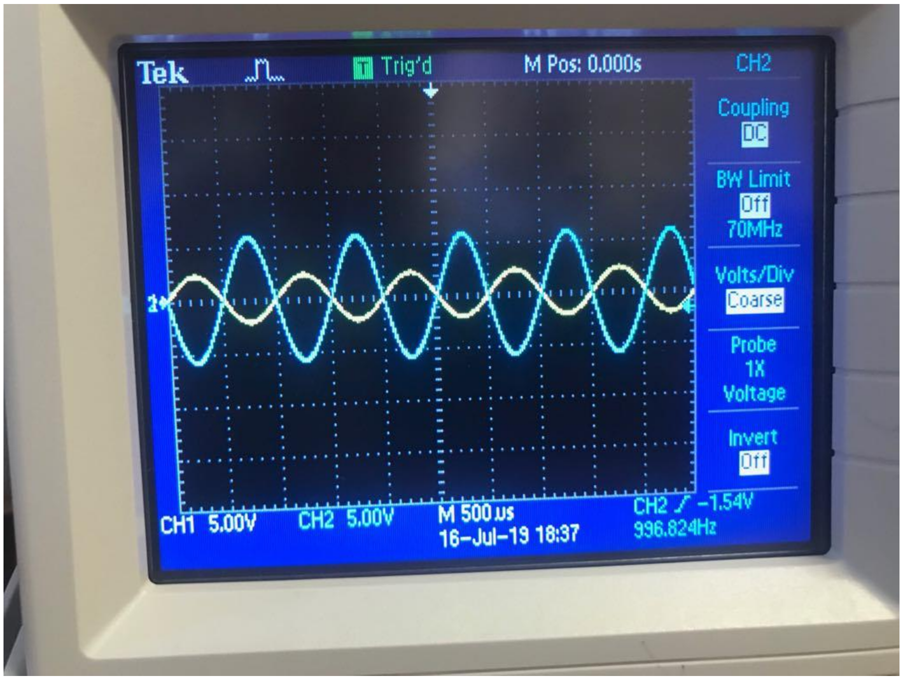


Figure 6

It could be seen from Figure 6, that the output is a inverted-scaled replica of the input, and that means that there is no distortion and the amplifier is working in the total 360° (the bias point is chosen such that it meets the maximum symmetrical swing case). And so, **the class of the amplifier is A.**

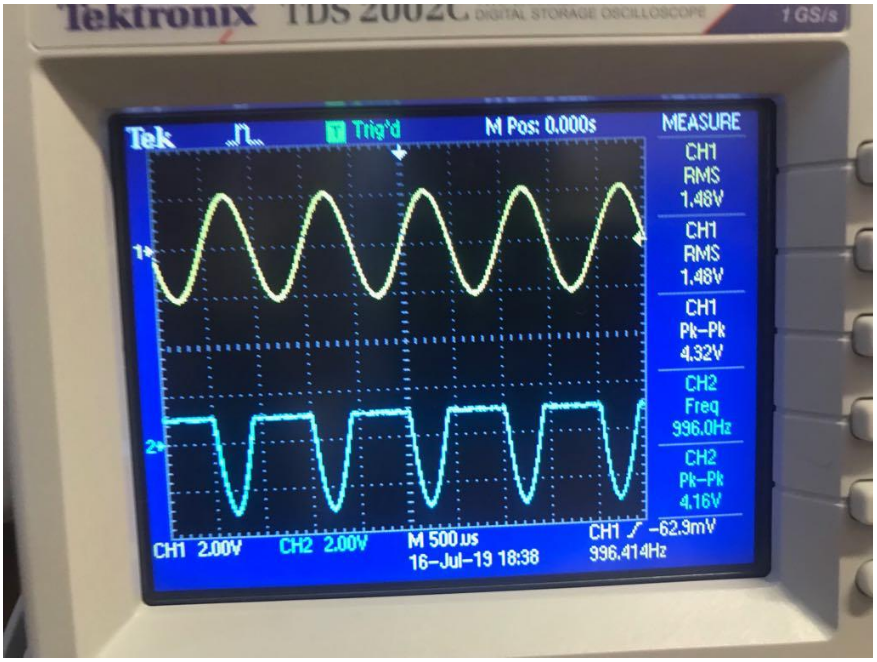


Figure 7

From Figure7, the amplifier is working in just half of the cycle (180^o), and that means that the bias point is not chosen to meet maximum symmetrical swing. In other words, **the class of the amplifier is B.**

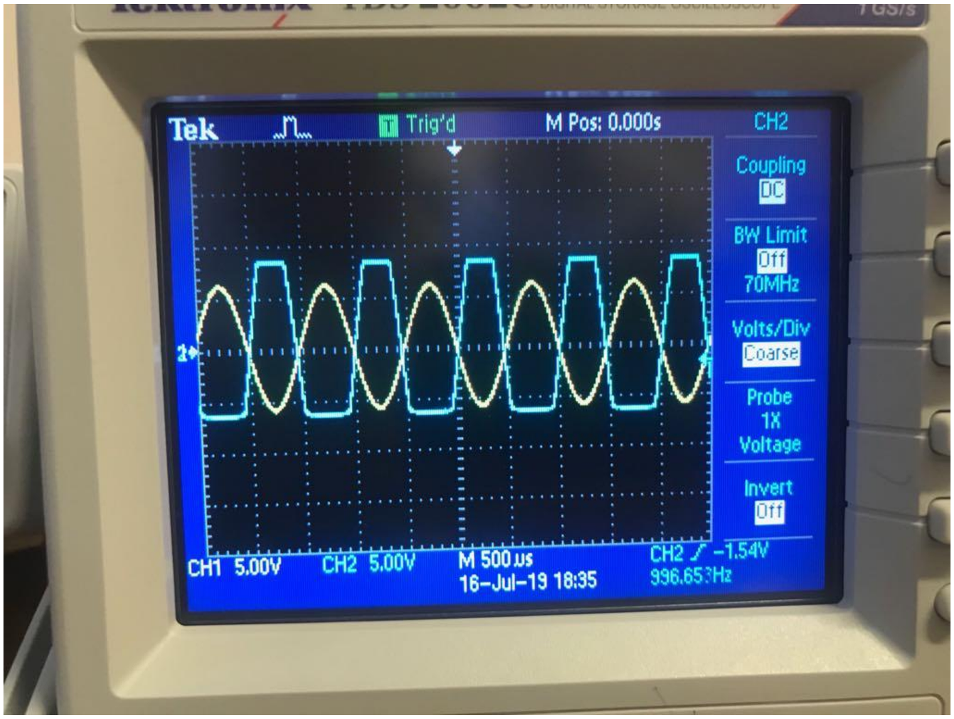


Figure 8

In Figure 8, both the upper and lower side of the output signal are distorted, and that means that the amplitude of the output signal is larger than the bias voltage (the output is a scaled of the input and that means that the factor times the amplitude of the input is larger than the bias voltage), than **the amplifier is not one of the basic classes.**

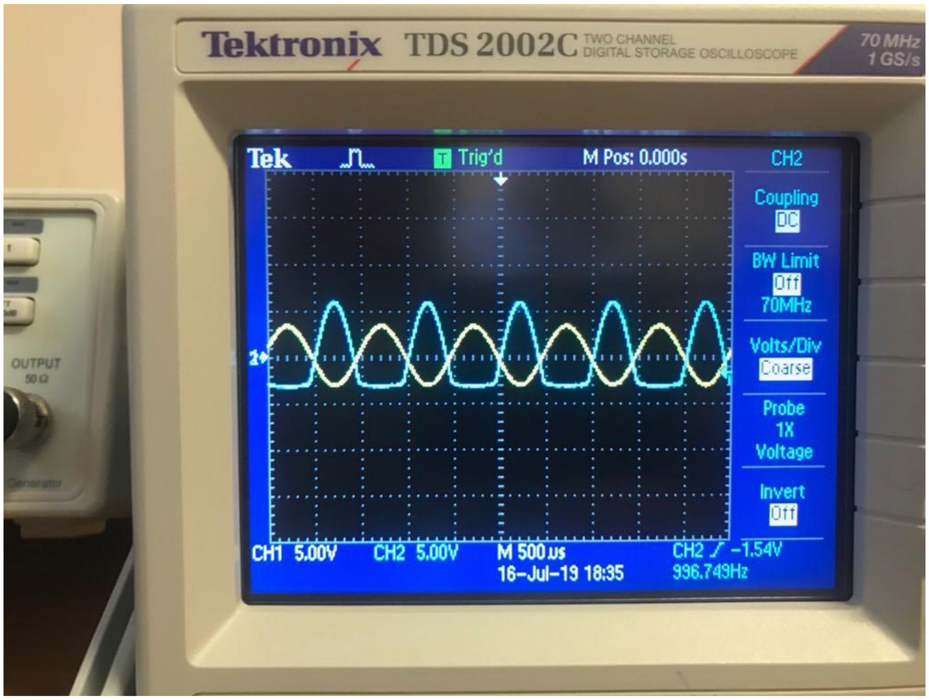


Figure 9

It could be seen from Figure 9 that the amplifier is working more than half of the cycle (greater than 180°), and that looks like class B but with bias voltage, which means that **the class of the amplifier is AB.**

II. Push-Pull Amplifier

1. The circuit in Figure 10 was connected.

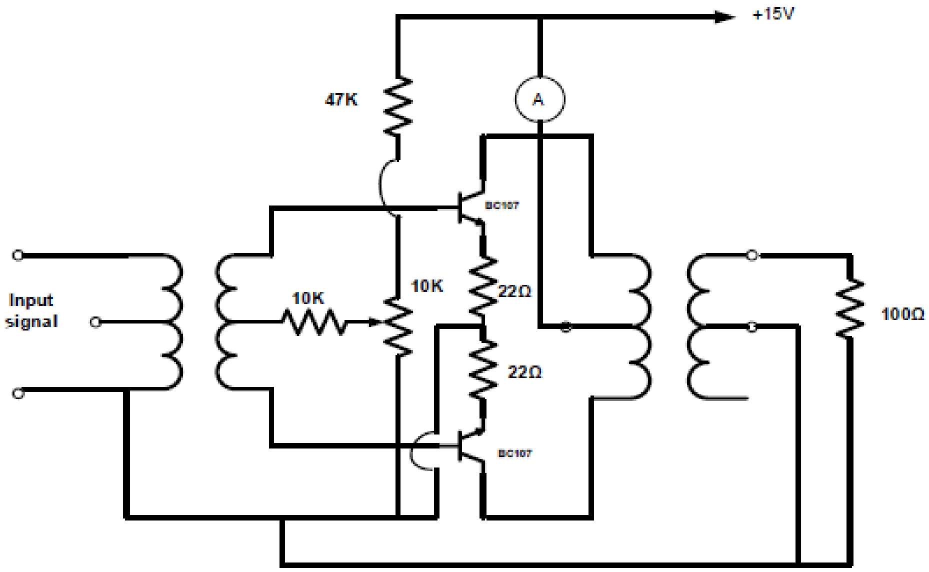


Figure 10

2. Using the potentiometer the DC supply current was set to zero.

3. The output of the function generator was turned up to give a 4 V_{p-p} and 1kHz frequency.

4. A photo was taken to the output of the previous setting.

5. The input signal was changed such that the amplitude is 0.5 V_{p-p}.

6.The output of the function generator was reset such that 4 V_{p-p} was got and the bias was used to eliminate the crossover distortion.

7 .Using variable resistor, the output RMS voltages was measured, and the results was recorded at Table 1.

8. The resistor that matches the output of the amplifier was selected and connected to the circuit, and then the function generator output was increased to the maximum value before the distortion occur.

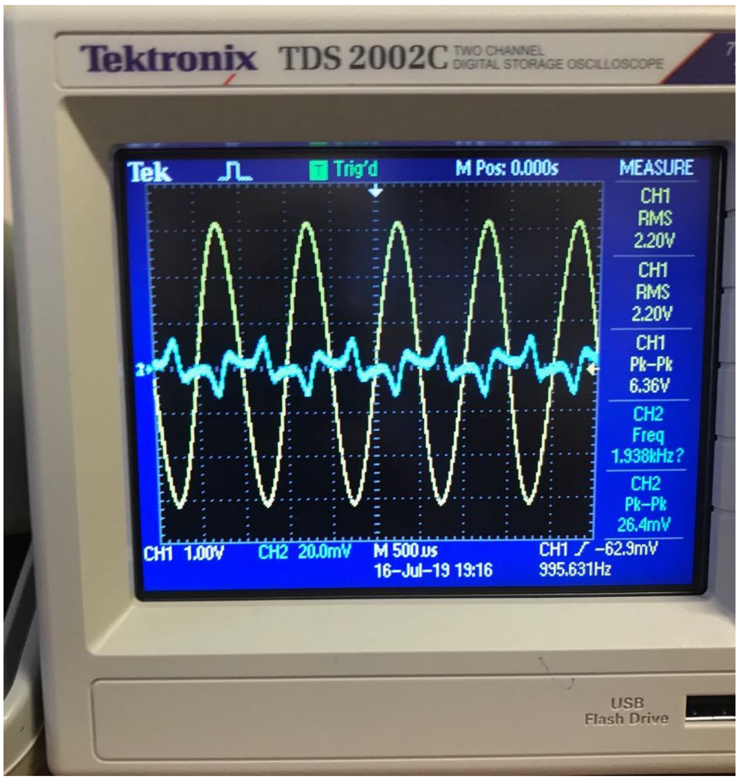


Figure 11: The Crossover Distortion in the Output Signal

The crossover distortion that occurs in Figure 11 due to the lacking of biasing; then the input signal itself is the bias for the transistor, then when the input signal is less than about ± 0.7, then the output is zero. Otherwise, there is an output.

Table 1

Resistor (Ω)	(Volts)		Power (mW)
	Peak-to-Peak	RMS	
320	46.8mV	16.546mV	0.00088
220	76mV	26.87mV	0.0039
150	60mV	21.21mV	0.003
100	2.84V	1.004V	10.1
69	2.42V	0.856V	10.6
50	1.72V	0.608V	7.369
41	920mV	325.25mV	2.58

The results were got using the formulas:

$$V_{RMS} = \frac{Vp{-}p}{2\sqrt{2}} \quad , \quad Power = \frac{Vrms^2}{Rload}$$

From the Table 1, the resistor that almost matches the output impedance of the amplifier is the resistor which gives the maximum power which is the **69Ω**. This result is got depending on the maximum power transfer theorem which states that the maximum power can be transferred to the load if the load impedance equals to the equivalent impedance seen by the load ($R_{Thevenin}$).

Then input current (the current of V_{cc}) is 7.76mA

- ➔ $P_{in} = V_{suppy} * I_{supply} = 15*7.76m=116.4mW$

Then the efficiency of the amplifier is

$$\eta = \frac{Pout}{Pin} \times 100\% = \frac{10.6}{116.4} \times 100\% = 9.1\%$$

It could be seen that the efficiency is very low in compare with the theoretical one (75%) and that is because the β of the transistors used is not equal, and due to the tolerance in the resistors.

III. Complementary Push-Pull Amplifier

1.The circuit in Figure 12 was connected

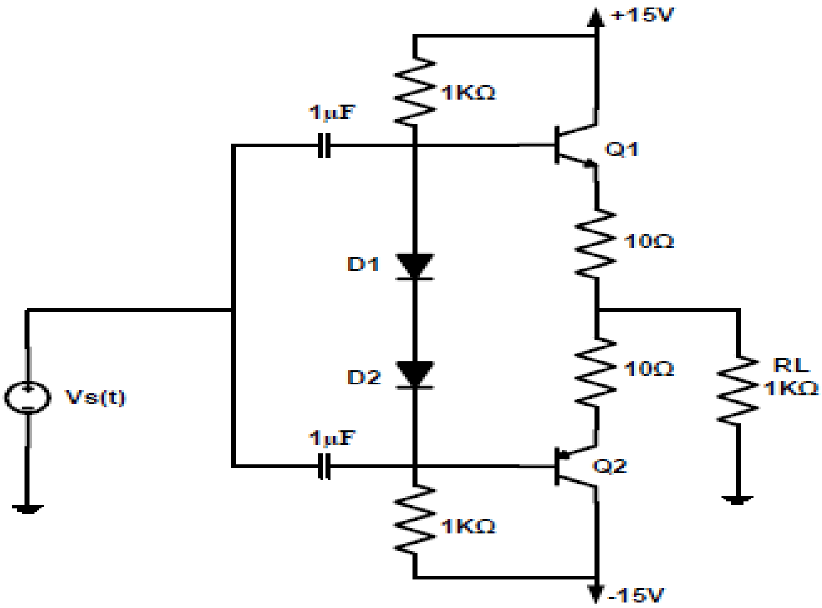


Figure 12

2.The output of the circuit was observed using oscilloscope, the current and the power efficiency for R_L =1kΩ and R_L = 100Ω where calculated, after measuring the supplies currents. All results were recorded in Table 2.

Table 2

R_{Load}	I_{suppy}	$P_{in} = V_{supply} \times I_{supply}$	$P_{out} = \frac{Vrms^2}{Rload}$	Efficiency ($\eta = \frac{Pout}{Pin} * 100\%$)
1kΩ	19.28mA	2×15×19.28=578.4mW	$\frac{318^2}{1k}$ =0.101mW	$\frac{0.101}{578.4}$=0.017%
100Ω	21.03mA	2×15×21.03=630.9mW	$\frac{149^2}{100}$=0.222mW	$\frac{0.222}{630.9}$=0.035%

The complementary push-pull amplifier is connected such that it prevents the occurrence (as much as possible) of the crossover distortion. However, since the connection is common collector, then the output signal is less than the input one.

Note that: the theoretical values are different from the practical ones due to the problems in the transistors, since the transistors are not identical as the theory assumed. And may the tolerance of the resistors affects the results. That is in addition to the approximation feature in the DMM and the oscilloscope.

Chapter 4 :Conclusion

The experiment gives a brief knowledge of the power amplifiers and how to differ between them and the differences between the classes based on the shape of the output and their efficiencies.

Chapter 5 :References

[1] Electrical and computer engineering department, circuit lab manual

[2] https://www.electronics-tutorials.ws/amplifier/amplifier-classes.html