# Briefly Analyze the Operating Characteristics of Push-Pull Amplifier Circuits, And Give Suggestions for Improvement in Combination with Specific CASES

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**Abstract.** In this information-based society, communication efficiency counts a lot, which is significant both at home and abroad. Equipment and technology of communication have also become more advanced and varied, thus people's experience of communication becomes better as well. People's need for communication devices is not only fast speed, but also low cost and high quality. In the communication system, the power amplifier acts as a key role, deciding the distance and quality of wireless communication. So in this situation, people try to find better amplifiers to meet higher requirements. This article introduces a good example: push-pull amplifier. By looking through previous articles and studies, this article introduces push-pull amplifiers' principle, feature and flaws, also giving some suggestions for advance and using online tools to help explaining. Finally get the conclusion that push-pull amplifiers do have its advantages in power amplification. This study not only enhances the understanding of push-pull amplifiers' critical role in modern communication systems but also provides valuable insights for optimizing their performance, ultimately contributing to more efficient and cost-effective wireless communication solutions.

**Keywords:** Push-Pull Amplifier, Falstad Simulation, Mos Tube

## 1 Introduction

Recent years, the development of the communication industry has entered a fast lane, and amplifier's performance, which is a key element in the communication industry, has also become more and more significant. Especially in wireless communication, a variety of new technics emerge, like wireless paging, cellular mobile communication technology. These new techs can't do with transmitting circuits, and power amplifiers are an indispensable part of all kinds of transmitting circuits. Thus, the quality of amplifiers would directly influence the effect of signal transmission. Generally, there are two indicators to measure an amplifier: efficiency and linearity. Higher efficiency means better energy transmission, while greater linearity stands for better


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communication quality. Common amplifiers can't reach both of the standards. So electric designers expect to invent amplifiers which could work in lower voltage supply situation with good amplification performance at the same time. Among these amplifiers, push-pull amplifiers have its distinct advantage. This article aims to analyze the advantages of push-pull amplifiers, explaining why they have such nice performance in amplification. Push-pull amplifier consists of a pair of transistors, working respectively during the positive and negative half periods, and the two collector currents alternate and superimpose on the load. [1] This article uses online tools to build a push-pull amplifier, analyzing its parameters. Also, this article points out some flaws of push-pull amplifier, enumerating some constructive study about improving it.

## 2 Main Body

### 2.1 Principle of push-pull amplifier

The core components of a push-pull amplifier are two transistors, one PNP and one NPN kind. The two transistors work in half the period respectively. As shown in figure 1, this is the push-pull amplifier circuit drawing with Falstad.

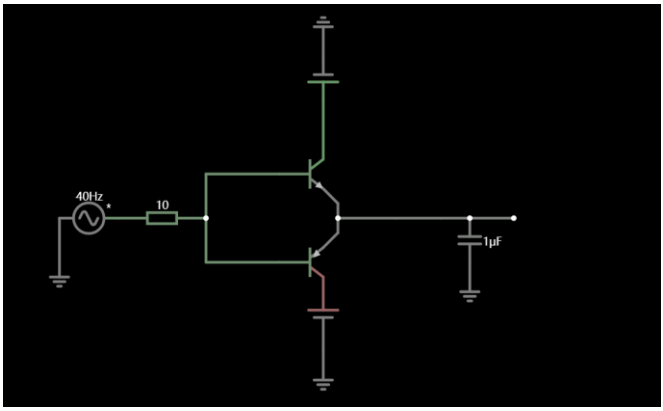


**Fig. 1.** Push amplifier circuit explanation (Picture credit : Original )

In a push-pull amplifier circuit, there are two power sources on each collector, whose polarities are opposite. When the input Ui is 0, there is no current in the amplifier, and the static operating points Ibq and Icq are both 0, which greatly reduces the amplifier's static losses. When there is an input, the amplification process of the push-pull amplifier is actually divided into two half-cycles. In the first half of the period, the positive source is turned on and now the NPN transistor is breakover. At this time the amplification is provided by the NPN-type transistor, while the PNP-type transistor is in the cutoff state. When the negative half-cycle is reached, the positive electrode is turned off and the negative electrode is turned on, at which time the PNP tube conducts and the NPN tube cuts off, with the PNP tube providing amplification,

so the amplifier is working in a whole cycle like this. At this point, the two transistors of the push-pull amplifier are said to be in the class B state, because their conduction angle is 180 degrees, that is, half a cycle, and the two transistors are working in their respective half-cycle amplification. Class B is juxtaposed with the class A and class A and B operating state. They are briefly described here first. Amplifiers in the class A state of operation conduct throughout the cycle, the conduction angle of 360 degrees, when the amplifier's efficiency can only reach a maximum of 25% [2]. This is because the transistor in class A operating state needs to keep the transistor on all the time, so the static current is larger and the loss is higher. Class A and B operating state of the conduction angle is located between class A and class B, that is, 180 degrees to 360 degrees.

### 2.2 The flaws of the B class push-pull amplifier

As mentioned earlier, the two transistors of the push-pull amplifier work in the class B operating state, that is, when the collector voltage switching, two transistors also switching conduction. Of course, the ideal situation is the voltage switching at the same time as the conduction of the tube is also switched. But in fact, due to the existence of the transistor's own conduction voltage, the switching will produce distortion, which is called crossover distortion. When the collector voltage at one end of the positive cycle decreases to less than the transistor on voltage, the transistor at that end will be cut off; similarly, when the negative half-cycle collector voltage at the other end has not increased to the transistor on voltage, the transistor at that end will also be cut off. As shown in Figure 2, the waveform is discontinuous at the transition point. Cross-over distortion is particularly noticeable when the input signal is weak, and the distorted waveform occupies a large portion of the waveform, weakening the performance of the amplifier.

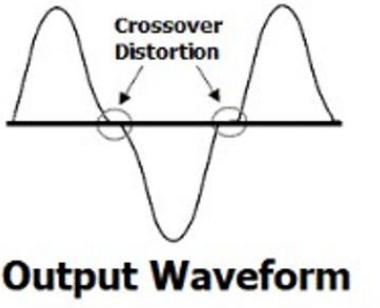


**Fig. 2.** Distortion waveform(Picture credit : Original )

Secondly, the push amplifier also requires dead time. This is because the transistor conduction cutoff is not as fast and accurate as the switch, there is bound to be a delay, so there may be two transistors on at the same time, then the amplifier will be

short-circuited. Therefore, it is necessary to set the dead time, that is, a transistor cut-off delay before another transistor conduction. The dead time should not be too long, otherwise it will lead to amplification vacuum[3].

### 2.3 A and B class push-pull amplifier

In order to avoid the crossover distortion that occurs during the Class B amplified state, the amplification circuit can be improved to avoid entering the cutoff region of the two transistors. This can be accomplished by adding two diodes between the two transistors. Diode D1 provides 0.7V for the positive half-cycle transistor and diode D2 drops 0.7V for the negative half-cycle transistor so that neither transistor enters the cutoff region, thus avoiding crossover distortion [4]. At this time, the conduction angle of both transistors is slightly more than 180 degrees, and so they are in class A and B operating conditions.

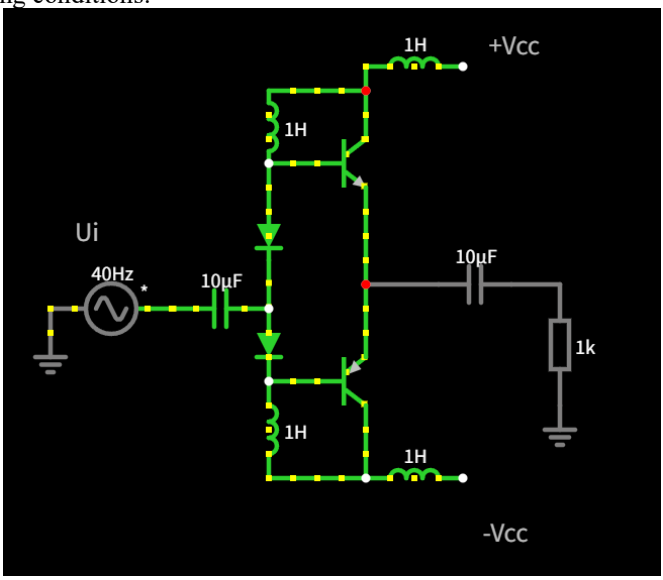


**Fig. 3.** Class A and B operating state circuits(Picture credit : Original )

### 2.4 Introducing more improvement options with specific applications of push amplifiers

**MOS tube push-pull amplifier circuit**. The push-pull circuits mentioned above all use triodes, and if the triodes are replaced by field effect transistors, namely MOS tubes, the circuit would be better. MOS tubes, compared to transistors, have a smaller voltage loss, which is 1/20 of transistors or so [5]. MOS tubes are divided into two categories of NMOS and PMOS, that is, the N-channel with P substrate and the P-channel with N-substrate. A parallel complementary differential input pair is realized using an NMOS differential pair and a PMOS differential pair [6], as shown in Figure 4. In this way, the NMOS differential pair operates when the circuit operates in the

positive half cycle, and the PMOS differential pair operates in the negative half cycle, while the two differential pairs work together during positive and negative cycle transitions. This gives us a more efficient amplification with less loss and no crossover distortion. In addition, the switching of the differential pairs is faster than the switching of two transistors, so that MOS tube push-pull amplifiers are widely used in data amplifiers for high-speed data transmission, such as USB 3.0, Thunderbolt, and other interfaces. Its high-speed switching characteristics and low-loss advantages can ensure that the data signal in the high-speed transmission process without distortion, no attenuation, to ensure accurate and rapid transmission of data.

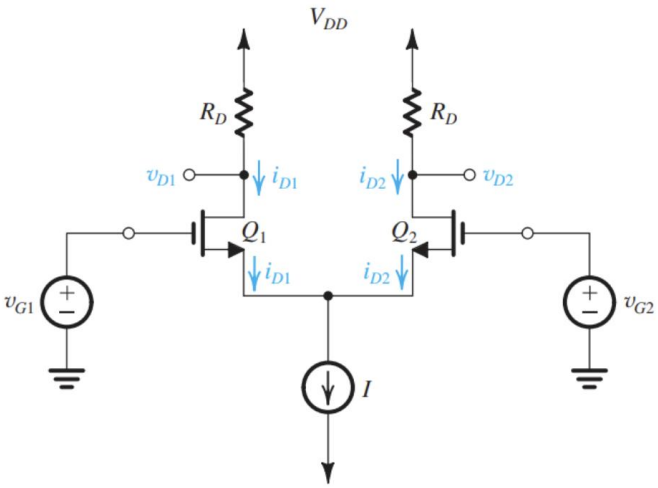


**Fig. 4.** MOS tube push-pull amplifier circuit(Picture credit : Original )

**Transformer-coupled push-pull power amplifier circuit**. Figure 3 shows that two loads need to be added at the same time as the diodes are added, and the value of the load also has an impact on the circuit performance, so how to find the best value of the load? Transformer coupling can be used to obtain the best load. The input voltage is introduced through the transformer, while the two transistors are combined into the output voltage through the N1, N2 turns of the transformer respectively, so as to achieve a better input and impedance matching[7]. Transformer coupled push-pull power amplifier circuits are widely used in inverter power supplies in the field of power electronics. Such as solar energy, wind energy and electrical energy conversion, the use of transformer coupling to achieve a good impedance matching, which makes the energy loss in the conversion process becomes smaller, more flexible according to the input voltage to adjust the turns ratio.

**NPN-NPN complementary push-pull structure amplifier circuit**. This is a single-supply power supply push-pull amplification structure, using two NPN-type transistors. The above-mentioned push-pill circuit structures use NPN and PNP transistors, but in fact, in practical production process, the InP, GaAs-based process is

widely used. The typical parameters of the two NPN and PNP transistors under this process have large differences [8], which can't be ideal as to achieve a good match. Simultaneously, the NPN-NPN structure is able to realize a small signal bandwidth of 0-830MHz, and at 100MHz, the output power to a 50Ω load is 20dBm. At an operating voltage of 12V, the DC loss of the circuit is 540mW, and the input and output impedances are matched up to 50 ohms [2], which has excellent efficiency and linearity.

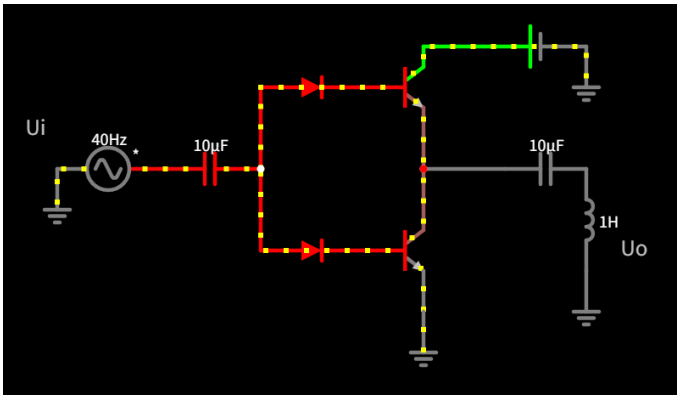


**Fig. 5.** NPN-NPN complementary push-pull structure amplifier circuit (Picture credit: Original )

In the signal processing circuits of some portable electronic devices, such as smartphones and tablet PCs, the NPN-NPN complementary push-pull structure provides reliable support for the device's wireless communication function through its single-side power supply, high efficiency, and linearity, which help extend the battery life of the device, in figure 5.

**Push-pull Amplifiers for Audio**. Here we compare the advantages and disadvantages of single-ended input and push-voice double-ended input. Single-ended input amplifier produces softer music, which can be full of emotion, but lacks grandeur of high pitch, and the ability to deal with a wide range of dynamic music is relatively weak; Push-pull amplifier produces music which has more powerful atmosphere, owing exciting staccato and dynamic sound range [9]. Therefore, the single-ended input amplification is often used in bars, restaurants and other similar places, while the push-pull amplified is used more in concerts, KTV and so on[10].

## 3 Conclusion

This paper introduces the principle of the push-pull amplifier, pointing out its working characteristics and advantages over the single-ended amplifier, and gives suggestions for improvement. By improving the structure of the push-pull amplifier circuit, the crossover distortion of the amplifier can be weakened, and at the same time, its linearity and efficiency can be improved, which is conducive to its better performance

in a variety of communication equipment. In the future, the status of wireless communication will continue to increase and the performance of amplifiers will also get better. As the material manufacturing process advances, the materials used for amplifiers will be superior, enabling the manufacture of transistor chips with higher integration and better amplification performance. Transistors will be able to have higher breakdown voltages. In addition, push-pull amplifiers can be integrated with other devices to achieve more precise functions, even combined with artificial intelligence to produce intelligent control chips which could adjust amplifier parameters in real time as needed. However, as the integration level increases, the noise interference will also increase, which will make the useful signals covered by noise, so in order to improve the integration level while reducing the noise, filtering, multiplexing technology, signal recovery and other technologies are also needed.

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