Analysis Of Low Offset Operation Amplifier Principles and Its Application Areas

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Abstract. While the functionality of traditional operational amplifiers today is no longer sufficient in areas that require high accuracy, low offset operational amplifiers are used in a wide range of applications in today's world. Compared with traditional operational amplifiers, low offset operational amplifiers have a series of advantages such as high precision and high signal-to-noise ratio, and are currently used in ECG signal acquisition, laser ranging, and plant electrical signal acquisition. Low offset op amps can amplify the signal with more accurately, which is advantageous in environments where the acquired signal is weak and the noisy is large, It mainly reduces the system offset by adjusting the input stage circuit (using the three-stage amplification circuit as the preamplifier circuit and using the two-stage amplification to prevent saturation of the preop amp), and improves the manufacturing process to reduce the structural offset to ensure the accuracy of the output signal. In the future, high integration and high accuracy will be the main development direction of operational amplifiers.

Keywords: Low offset operational amplifier; ECG signal acquisition; laser ranging; plant electrical signal acquisition.

1. Introduction

With the development of modern electronic information technology and sensors, electronic devices require higher and higher accuracy, the signal to be collected is smaller than ever, and the standard of removing noise is gradually increasing, traditional operational amplifiers can no longer meet today's needs [1]. Low-offset operational amplifier can effectively solve these problems, and this article focuses on the application of low offset operational amplifiers in various areas.

Low-offset operational amplifiers address system offset by employing symmetrical difference graded input stages and structural offset by improving the manufacturing process. Compared with traditional operational amplifiers, the output signal of low-offset operational amplifiers is more accurate, and the response speed is faster, which effectively improves the shortcomings of traditional operational amplifiers and makes them more widely used. At present, low-offset operational amplifiers are required in the fields of ECG signal acquisition, plant electrical signal acquisition and laser ranging, and low-offset operational amplifiers can amplify the collected signals more accurately and make the measured data more accurate. At the same time, the current operational amplifiers still have problems such as output signal distortion and large power consumption, so high integration and high accuracy are the main directions of future development. This study will help readers understand the principles and advantages of low offset operational amplifiers in various fields and discuss the current problems and future development of operational amplifiers.

2. Analysis of the basic principles of low offset operational amplifiers

2.1. Traditional operational amplifiers analysis

2.1.1 Basic principle

An operational amplifier is an integrated circuit composed of many transistors and is a multi-terminal device widely used at present. The operational amplifier has three ports, two input and one output. When the input voltage is input from the '+' port, the output voltage direction is the same; When the input voltage is input from the '-' port, the output voltage direction is the same; When two

input ports input voltage at the same time, the output voltage is in the same direction as the side with the greater input voltage.

In an ideal state, the input resistance of the operational amplifier is infinite and the output resistance is treated as zero. There is no current between the input ports, which can be considered 'virtual open'. An ideal op amp has an infinite magnification, which means two input ports have the same voltage, which can be considered 'virtual shortness' [2]. The basic circuit diagram is shown in Figure 1 below.

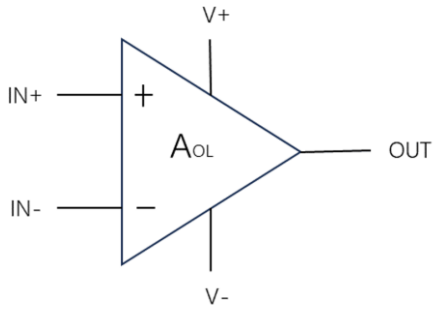


Fig. 1 Basic circuit diagram (Photo/Picture credit: Original)

2.1.2 Characteristic analysis

Although the structure of traditional operational amplifiers is simple and the price is low, there are many shortcomings, such as offset voltage, limited bandwidth, and problems such as bias current and noise. Most of the current electronic technologies require high-precision, high-stability, low-power operational amplifiers, and simple operational amplifiers cannot meet their requirements.

2.2. Low offset operational amplifier analysis

2.2.1 Basic principle

System offset and random offset are the main reasons for the offset of the operational amplifier, the input stage structure of the circuit itself is asymmetrical will cause system offset, and random offset will be caused due to process defects in the production process of the circuit [3]. The solution of system offset mainly adopts symmetric difference graded input stage design, while reducing random offset mainly relies on laser tuning technology, chopping technology and other methods.

A low offset operational amplifier consists of three stages of circuitry, one for the input, an intermediate stage, and an output stage. The input stage primarily affects the operational amplifier offset, so a differential input stage is used to compensate for the bias current of the input stage by connecting the differential input port to a paranoid current compensation circuitry. The gain and output capability of an operational amplifier are primarily determined by the intermediate and output stages. The reference circuit determines the bias current throughout the circuit, and the magnitude of the bias current determines the quiescent current of the circuit. Protection circuitry reduces the output signal and prevents the output signal from exceeding the maximum [3]. The circuit block diagram is shown in Figure 2 below [3].

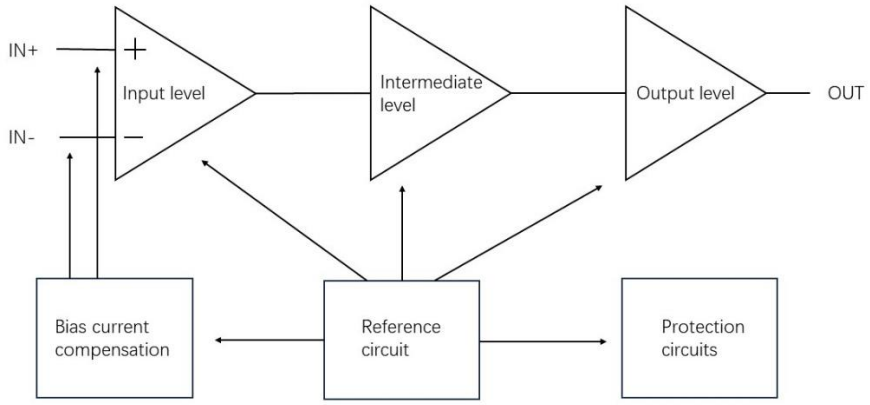


Fig. 2 Circuit block diagram [3]

2.2.2 Characteristic analysis

Compared with traditional operational amplifiers, the output signal of low-offset operational amplifiers is more accurate, with low noise, not easy to be interfered by other signals, low drift, faster response and other advantages.

3. Application areas

3.1. ECG signal acquisition

ECG signal acquisition first detects the required biology current through the ECG electrode, and then you pass the captured signal to the signal collector, and the final output is often in the form of an electrocardiogram. The ECG signal is only between 0.05mV - 5mV, which is very weak, and because the human skin resistance is very high, the measured voltage is very easy to drift due to physical activity [4]. Therefore, the amplifier is required to have the characteristics of low noise, low power consumption and high common-mode rejection ratio, low drift, and small nonlinearity.

The three-operation amplification circuit is usually used as a pre-amplification circuit, and in order to reduce the baseline drift, a high-pass filter and compensation circuits need to be connected to this amplifier to reduce the noise of other signals in the human body [5]. After the ECG signal is collected, most of them need to be amplified to the V level before they can be observed, so the magnification requirements are very large. However, the DC stability of the circuit depends on the primary amplification gain, and if the primary amplification gain is too large, the preamplifier will be saturated, so the two-stage amplification method is used. The circuit diagram is shown in Figure 3 below [5].

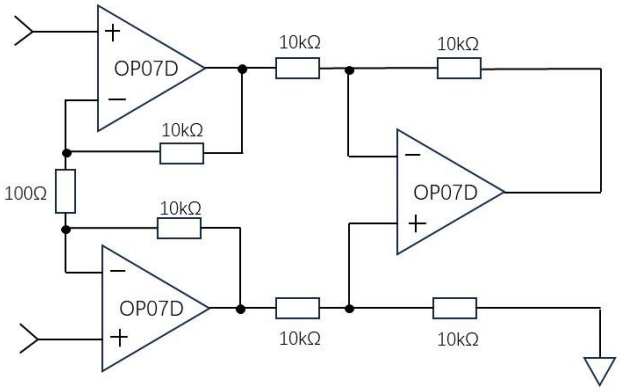


Fig. 3 AD620 Biomedical amplifier block diagram [5]

After passing through the pre-amplification circuit, although the required signal has been amplified, it still cannot reach the amplitude required for the final measurement, so it is necessary to connect a main amplification circuit after the pre-amplification circuit to continue to amplify the signal so that the measured signal reaches the specified range. This amplifier is not easy to be affected by temperature in biomedical signal acquisition, reduces the influence of the rest of the human body signals on target signal acquisition, the circuit power consumption is small (ideally only 3V power supply is required), and the sensitivity is high [6]. The circuit diagram is shown in Figure 4 below [6].

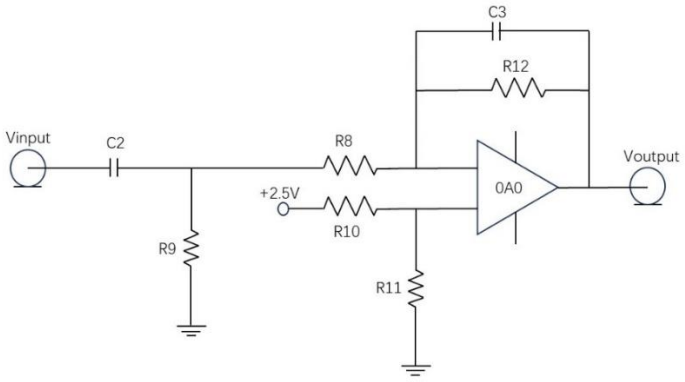


Fig. 4 Schematic diagram of the main stage amplification circuit [6]

3.2. Laser ranging

Laser ranging is determined by measuring the round-trip time of the laser from the place of emission to the place of measurement. The amplifier needs to convert the diffusely reflected laser light into an electrical signal, and for the accuracy of the measurement, it needs to amplify the signal as undistorted as possible and increase the magnification to avoid noise interference [7]. The function is realized in the form of a preamplifier connected to the main amplifier, and the voltage is amplified by the main amplifier after noise is reduced by the preamplifier.

The preamplifier in this circuit adopts the form of a triode circuit, which is composed of a common-emission stage amplification circuit and a common-collector amplification circuit. The common collector amplifier acts as impedance matching because its input resistance is large, and its output resistance is small. Common-emission stage amplification circuits are used to provide the voltage gain required by the circuit and stabilize the circuit. The preamplifier bandwidth is about 100MHz, and the feedback resistance of the amplifier is 47KΩ [8]. The circuit diagram is shown in Figure 5 below [8].

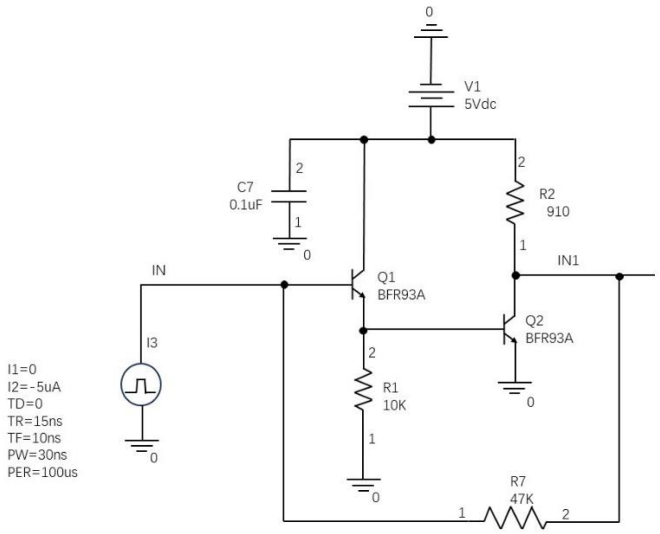


Fig. 5 Preamplifier circuit schematic [8]

The main amplifier further amplifies the signal output by the preamplifier so that it meets the requirements of the subsequent circuit. This amplifier has a voltage gain of approximately 32times, a saturated input current of 10uA, and a bandwidth of approximately 50MHz [8]. The advantage of this operational amplifier including high measurement accuracy, fast response speed, wider bandwidth, high signal-to-noise ratio and not easy to be disturbed by noise. The circuit diagram is shown in Figure 6 below [8].

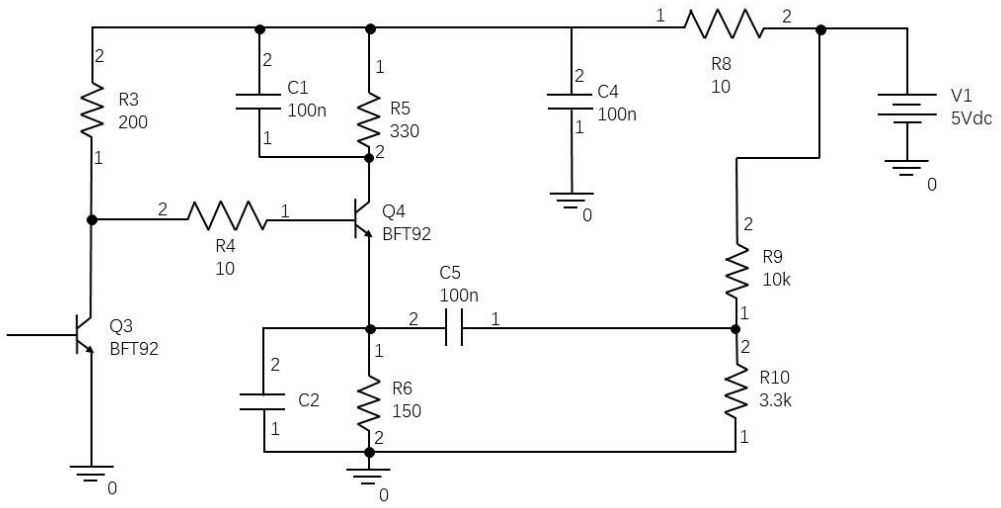


Fig. 6 Schematic diagram of the main amplifier circuit [8]

3.3. Plant weak current signal acquisition

Plant electrical signal is a physiological signal, with high impedance and weak signal. The range is between a dozen and hundreds of millivolts, and the interference in the process of acquiring signals mainly comes from power frequency interference and polarization voltage. Power frequency interference has a large amplitude and exists in common-mode form, so a high common-mode rejection ratio is one of the necessary conditions for amplifiers. The polarization voltage is generated because a chemical galvanic cell with a large DC voltage will be formed between the acquisition electrode and the acquisition object, so the gain of the first stage amplification circuit should not be too large [9].

The Pre-circuit of Bio amplifiers is dominated by the pre-stage amplification circuit of the noninverting parallel structure, this amplifier is a three-operation amplification circuit, the first stage amplification consists of two operational amplifiers connected in parallel in phase, thereby improving the amplifier input impedance and gain, and the second stage amplification consists of a differential amplification. The common-mode rejection ratio of the first amplification and the common-mode rejection ratio of the second amplification are the main factors affecting the common-mode rejection ratio of the circuit. To change the magnification of this amplifier, you can change the values of R1, R2, R3, R4, so it is convenient to adjust the magnification. The circuit has a high input impedance, because the characteristics of the operational amplifiers A1 and A1 are the same, and A3 is a differential circuit that reduces the drift voltage caused by A1 and A2 and has a low output impedance [10]. The advantage of this operational amplifier including high data acquisition accuracy, not easy to be interfered by noise; The circuit is simple and easy to debug; The offset voltage is low, and the common-mode rejection ratio and input impedance are high. The circuit diagram is shown in Figure 7 below [10].

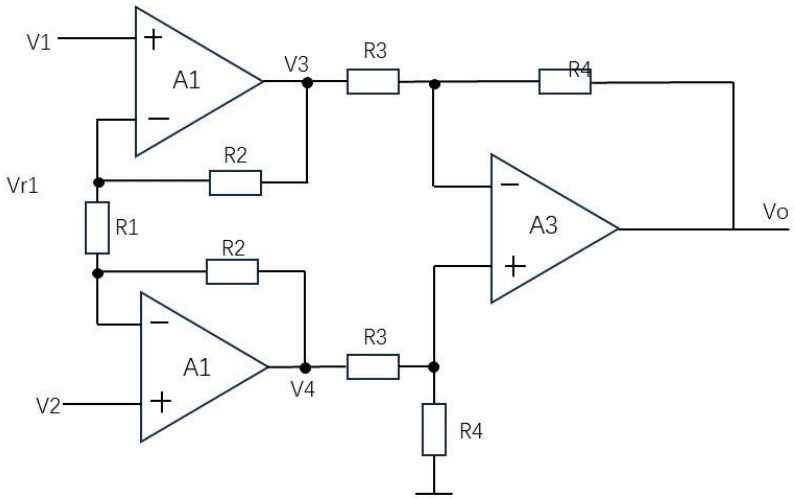


Fig. 7 Preamplifier circuit schematic [10]

4. Challenges and prospect analysis

4.1. Solvable problems

Currently, low offset operational amplifiers are primarily used to solve the following problems: Firstly, low offset operational amplifiers are currently mainly used to measure microelectronic signals and signals that are easily disturbed by noise. It can amplify the data information that is usually difficult to collect for subsequent circuits, and at the same time ensure that the signal is not distorted to the greatest extent and that the amplifier has a large gain. Secondly, sensors are indispensable in today's world, when collecting most of the world's signals, we need to convert the measured signals into our measurable electrical signals with the help of sensors, and the higher the accuracy of the sensor, the more accurate the measurement signal. Low offset operational amplifiers are essential if the sensor is to be characterized by high accuracy.

4.2. Future development and prospects

At present, electronic components are developing in the direction of high precision, high professionalism and high integration. In the future, operational amplifiers will be more accurate and tend to be ideal for amplification situations. The magnification will increase a lot and the distortion of the output signal will be much improved, allowing us to measure small signals that we cannot currently collect more easily and accurately. In terms of signal acquisition, it is also possible to collect data more accurately, so that the sensor becomes more accurate. The high level of integration allows the operational amplifier to have more functions, allowing it to meet more complex requirements. At the same time, the power consumption of the operational amplifier should also be reduced to meet the needs of various portable devices, such as built-in pacemakers, portable measurement devices and other tools.

5. Conclusion

The results of this paper from the study of low offset operational amplifiers are as follows:

Firstly, the low offset operational amplifier reduces the system offset by the input stage circuit structure and reduces the structural offset by improving the manufacturing process. It is more accurate than traditional operational amplifier output signals and can be used in a wider range of applications.

Secondly, in ECG signal acquisition, laser ranging and plant electrical signal acquisition, the signal to be collected is very small, and the noise is large. This requires the operational amplifier to output

the signal without distortion and to improve the signal-to-noise ratio. Low-offset operational amplifiers typically use a three-op amplification circuit as a preamplifier circuit to prevent saturation of the preoperational amplifier by employing two stages of amplification.

Thirdly, low offset operational amplifiers are currently used in many applications, which can make the output signal more accurate, which is conducive to measuring the signal of interest. The high level of integration allows the operational amplifier to have more comprehensive functions, which can solve many complex problems; High accuracy makes the output signal more accurate. These two directions are the main directions for the future development of operational amplifiers.

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