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Improvement of partial voltage accuracy of photomultiplier bias circuit in life science instrument

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Abstract: Photomultiplier tube (PMT) is a commonly used optical detection device in life science instruments, and its performance is crucial to the accuracy and sensitivity of the instrument. This article provides a detailed analysis of the accuracy of PMT bias circuits and proposes some improvement methods to enhance the performance of PMT. By introducing temperature compensation and stability improvement techniques, we have successfully suppressed the adverse effects of temperature and parameter drift on the PMT bias circuit, thereby improving the accuracy and stability of voltage division. The experimental results indicate that these improved methods have made significant progress in the application of photomultiplier tubes in life science instruments, providing effective solutions for precise measurement and reliability of the instruments. These improvement methods provide useful guidance and reference for further improving PMT performance and developing more advanced life science instruments.

1. Introduction

As a commonly used optical detection device in life science instruments, photomultiplier tube plays an important role in biolrescence detection, protein analysis and other fields. However, the performance of PMT is affected by many factors, among which the partial voltage accuracy of the bias circuit is one of the key factors. The partial accuracy of PMT directly affects the sensitivity and accuracy of signals, so it is important to improve the partial accuracy of PMT bias circuit. In this paper, the partial accuracy of PMT bias circuit is studied and improved. First, through the temperature compensation technology, we introduce the temperature sensor and the compensation circuit to monitor and correct the effect of the temperature change on the PMT bias circuit in real time. By measuring the temperature and adjusting the parameters of the resistance or amplifier accordingly, we were able to provide a stable partial pressure ratio at different temperatures. Secondly, through the stability improvement method, we choose the components with better stability, and adopted negative feedback technology and temperature stable power supply to reduce the influence of parameter drift and fluctuation on the partial pressure accuracy. Moreover, we perform a thermal design to optimize the layout and heat dissipation of the components and reduce the temperature gradient and thermal coupling effects[1] .

2. Photomultiplier tube offset circuit analysis

2.1. Role and principle of the bias circuit

Photomultiplier Photomultiplier Tube (PMT) is a highly sensitive photoelectric conversion device commonly used for optical detection. In order to function properly and to maximize its performance, the PMT requires a reliable and precise bias circuit to provide the appropriate operating voltage. The function of the bias circuit is to convert the DC supply voltage to the PMT and maintain its stability. The principle of PMT is based on photoemission and electron multiplication effects. When the photon enters the temporal pole of the PMT, the photon triggers a photoemission effect, converting the photon into electrons. These electrons go through a series of multiplication processes, through a series of secondary emission and multiplication cascade, generating large numbers of electrons that amplify the light signal. The main principle of the bias circuit is to reduce the DC power supply voltage to the voltage range suitable for the normal operation of the PMT. The-voltage circuits usually consists of resistors and capacitors, whose selection and configuration depend on the working requirements of the PMT. In the bias circuit, the resistor is used for the partial voltage to steadily reduce the high voltage to the suitable operating voltage. Capacitors are used to filter and reduce noise to ensure the stability and reliability of the bias circuit. The design of bias circuits needs to take into account multiple factors. First, the working voltage of PMT must be just right, too high or too low will affect its performance and life. Secondly, the bias circuit needs to have good stability to ensure the continuity and reliability of the working voltage[2] . Moreover, the bias circuit should also have low noise and high precision to maximize the sensitivity and signal to noise ratio of PMT. Bioffset circuit plays an important role in the normal operation of photomultiplier tubes. Through rational design and optimization of partial voltage circuit, stable and accurate working voltage can be provided, so as to fully realize the performance of photomultiplier tube and meet the needs of various optical detection and measurement[3] .

2.2. Common bias circuit design scheme

There are many common bias circuit design schemes, some of which include: resistance partial voltage circuit: this is one of the simplest and most common bias circuit design schemes. It uses two resistors to divide the DC supply voltage to the appropriate operating voltage range. One of the resistance is connected to the DC power supply and the other is connected to the photomultiplier and connects it to the ground. By selecting the appropriate resistance value, the desired operating voltage can be achieved. Voltage reference circuit: This design uses a regulator or accurate voltage reference source as input to the bias circuit. The voltage regulator can provide a stable output voltage, while the voltage reference source can provide an accurate reference voltage. This scheme can provide a more stable and reliable working voltage, and have a better anti-interference ability for the fluctuation and change of the input power supply. Feedback control circuit: This design uses feedback control technology to achieve accurate bias voltage[4] . It generally includes a comparator or operational amplifier for comparing the actual operating voltage with a preset target voltage. Based on the comparison result, the feedback control circuit automatically adjusts the output voltage to keep it near the preset target value. This scheme has a high accuracy and stability. Digital control circuit: With the development of digital technology, the bias circuit scheme of digital control is becoming more and more common. This scheme uses digital circuits and microcontrollers to achieve precise control and regulation of the bias voltage. Through programming and algorithms, automated bias voltage adjustment can be implemented to accommodate different working conditions and requirements. These common bias circuit design schemes have advantages and disadvantages, choosing schemes suitable for specific applications need to consider the actual requirements, cost, accuracy and stability factors. Meanwhile, for more advanced and complex applications, it may need to combine multiple solutions or conduct customized designs to meet specific requirements and performance requirements[5] .

3. Influencing factors of partial pressure accuracy of bias circuit

3.1. Effect of photomultiplier characteristics on partial pressure accuracy

The characteristics of photomultiplier tube (Photomultiplier Tube, PMT) have an important influence on the partial accuracy of bias circuit. First, the PMT has a specific operating voltage range, beyond which it can cause performance degradation or even damage. Therefore, the bias circuit design must consider the operating voltage range of the PMT to provide the appropriate operating voltage. Second, the output current of the PMT is proportional to the input light signal intensity. Therefore, the bias circuit needs to consider the range of the PMT output current to ensure that the output signal can be properly processed and amplified to avoid overload or distortion. In addition, the PMT in different working modes has different impedance characteristics. Therefore, bias circuit design needs to select the appropriate resistance and capacitance value according to the impedance characteristics of PMT to ensure the matching of partial voltage accuracy and signal transmission. Moreover, the working performance of the PMT is affected by the temperature. The temperature change leads to changes in the operating voltage and gain of PMT, which then affects the partial voltage accuracy. Therefore, the bias circuit design needs to consider the temperature compensation and stability measures to ensure that a stable operating voltage is still provided at different temperatures[6] . In addition to the above factors, the noise characteristics, linearity and dark current of the photomultiplier tube will also affect the partial voltage accuracy of the bias circuit. Noise characteristics require noise filtering and suppression in bias circuit design to ensure signal clarity and accuracy. Linearity involves the linear relationship between the output and the input of PMT. The bias circuit design needs to ensure that the output signal can maintain a certain linear relationship under different input light intensities. Dark current refers to the output current generated by PMT in the absence of light exposure. The offset circuit needs to reduce the influence of dark current as much as possible to improve the partial voltage accuracy and signal-to-noise ratio. The characteristics of photomultiplier tubes have important influence on the partial accuracy of bias circuit. In the bias circuit design, it is necessary to consider the working voltage range, output current characteristics, impedance characteristics, temperature influence, noise characteristics, linearity, and dark current of PMT to ensure a stable and accurate working voltage and maximize the performance of photomultiplier tubes[7] .

3.2. Impact of bias circuit components and parameters on partial pressure accuracy

The components and parameters of bias circuit have important influence on the partial accuracy. Resstor is one of the most basic components in bias circuit, and its resistance value and accuracy directly affect the accuracy of partial voltage. Choosing a resistor with suitable accuracy can provide a stable partial voltage ratio but will also introduce voltage drift. Capacitors are used in the bias circuit to filter and stabilize the working voltage, and their capacity value and loss factor will also affect the accuracy of the partial voltage. A large capacitor capacity value provides better filtering effect and stability, but also increases the response time and power consumption. Operational amplifier is used to amplify and adjust the operating voltage in some bias circuits, and its voltage gain and offset voltage drift will directly affect the partial voltage accuracy. Choosing the appropriate operational amplifier is the key to achieve high score pressure accuracy. Moreover, the temperature compensation circuit is used to correct the effect of temperature change on the partial accuracy, where the accuracy of the temperature sensor and the design of the compensation circuit have an important impact on the partial accuracy. When designing the bias circuit, it is necessary to carefully consider the selection and parameter setting of resistors, capacitor, operational amplifier and temperature compensation circuit, so as to balance the accuracy, stability, response time and power consumption, so as to achieve high precision partial voltage separation function[8] .

4. Methods and techniques for improving the partial pressure accuracy

4.1. Selection and use of high-precision components

To improve the pressure and accuracy of bias circuit, some methods and techniques can be adopted. Among them, the selection and use of high-precision components is a key step. First, it is crucial to select resistors with high precision. High-precision resistors can provide more accurate resistance values, thus achieving a more stable partial pressure ratio. When selecting a resistor, a metal film resistor or precision resistor, which has a lower temperature coefficient and smaller resistance drift, can provide higher accuracy and stability. Secondly, it is also important to select capacitors with high accuracy and stability. High-precision capacitors can provide a more accurate capacity value and a lower loss factor, thus achieving a better filtering effect and stability. When selecting capacitors, multilayer ceramic capacitors or metallized polyimide capacitors, which have smaller tolerance drift and lower loss factors, can provide higher accuracy and stability. In addition, the selection of high-precision operational amplifier is also an important factor to improve the accuracy of partial pressure. The high-precision operational amplifier has low bias voltage drift and small input bias current, which can reduce the errors and improve the accuracy of signal amplification. When selecting an operational amplifier, you can consider using a precision operational amplifier or a zero drift amplifier, which has higher gain accuracy and smaller drift, and can provide higher partial pressure accuracy. Moreover, temperature compensation techniques can also be used to improve the partial pressure accuracy. By using temperature sensors and corresponding compensation circuits, the effect of temperature change on the partial pressure accuracy can be monitored and corrected in real time. Temperature compensation technology can effectively reduce the error caused by temperature, provide stable working voltage, thus improving the accuracy of partial voltage[9] .

4.2. Application of noise suppression and filtering technology

Noise suppression and filtering techniques play an important role in improving the partial accuracy. To effectively reduce noise interference and improve the accuracy and reliability of signals, a series of noise suppression and filtering techniques can be applied. First, the noise suppression technique can be used to reduce the noise interference in the bias circuit. Simplifying the signal path is an effective noise suppression method, reducing the influence of noise on the system by reducing the interference source and coupling during signal transmission. Optimizing wiring to reduce cross interference between power lines and signal lines is an important measure. In addition, a good grounding and shielding design can also effectively inhibit the external electromagnetic interference. Proper grounding and shielding technology can reduce the interference of noise and improve the anti-interference ability of the system. Power power filtering technology is another common noise suppression method, which provides a stable working voltage by removing the high frequency noise on the power cord by using the power voltage filtering circuit. Secondly, the application of filtering technology is crucial to improve the accuracy of partial pressure. The filtering technology can effectively suppress noise and interference signals and improve the accuracy and stability of the system. The RC filter is one of the commonly used filtering techniques for filtering signals for a specific frequency range through a combination of resistance and capacitance. As desired, appropriate RC filter parameters can be selected to suppress the noise and interference. Low-pass filter is another common filtering technology, which is mainly used to remove the high-frequency noise, retain the low-frequency signal, and make the output signal smoother. Common low-pass filters include Butterworth filters and Chebyshev filters, etc. Moreover, the digital filter is a filtering technology based on a digital signal processing algorithm that enables accurate filtering of the signal. The digital filter can select the appropriate filter algorithm and parameters according to the specific requirements to achieve accurate noise suppression and filtering effect[10] .

4.3. Temperature compensation and stability improvement method

First, temperature compensation is a commonly used method to counteract the effect of temperature changes on the partial pressure accuracy. Temperature has a great influence on the characteristics of components such as resistors, capacitors and amplifiers, resulting in the partial pressure ratio changing with temperature. To solve this problem, a temperature sensor and a compensation circuit can be used to monitor and correct the effect of temperature change on the partial pressure accuracy in real time. By measuring the temperature and adjusting the parameters of the resistance or amplifier accordingly, a stable partial pressure ratio can be provided at different temperatures. In addition, a temperature compensated resistance or temperature compensation capacitor can be used to offset temperature-induced errors, thereby improving the accuracy and stability of the partial pressure. Secondly, the stability improvement method can be used to reduce the drift and fluctuation of the bias circuit and improve the stability of the partial voltage. Drift refers to the change of bias circuit parameters over time, while fluctuation refers to the change of parameters in a short time. These factors can lead to a reduction in the partial pressure accuracy. In order to improve stability, the following measures can be taken: select components with better stability: preferably high precision components with smaller temperature coefficient and smaller drift, such as resistors and capacitors with better stability. These elements have smaller parameter variations and are able to provide a more stable partial pressure ratio. Negative feedback: Using the negative feedback technology can improve the stability of the system. By introducing negative feedback into the bias circuit, the influence of parameter drift and fluctuations on the output can be reduced. Negative feedback is able to provide a more stable work point and less sensitivity to temperature and other environmental factors. Temperature stable power supply: the use of temperature stable power supply can reduce the impact of power supply voltage drift on the accuracy of partial voltage. A stable power supply can provide a stable operating voltage, reducing the error and drift. Thermal design: Reasonable thermal design can improve the stability of bias circuits. By optimizing the layout and heat dissipation design of the components, the temperature gradient and the thermal coupling effect can be reduced, and the influence of the temperature change on the partial pressure accuracy can be reduced.

5. Conclusion

This paper studies and improves the partial accuracy of photomultiplier tube in life science instrument. We have successfully improved the performance of PMT with temperature compensation and stability improvement techniques. The improved PMT bias circuit has higher voltage separation accuracy and stability, which can accurately detect optical signals and improve the sensitivity and accuracy of the instrument. This study provides a useful reference for the application of PMT in life science instruments and provides new ideas for further improving the performance and stability of optical detection devices.

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