

The Design and Implementation of 10us Filtering and Shaping Amplifier

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Abstract

As is well known, nuclear power is an important part of nuclear technology research. It is an interdisciplinary subject based on radiation detection technology and electronic technology. Nuclear electronics technology rapid development in recent years, which has resulted in the measuring process of the progress of the need to measure the energy resolution of the nuclear signal is higher and higher, leading to the traditional pulse amplifier output signal after can't meet the requirements of follow-up, in order to satisfy the corresponding conditions, to develop more effective amplifier, this makes the spectrometer amplifier to come out, spectrometer amplifier is also known as linear amplifier or linear pulse amplifier. Conventional amplifier is usually divided into two parts, preamplifier and main amplifier, the preamplifier is on the front end the detector was used to preliminarily collected signal amplification, is compared to the preamplifier and main amplifier, it will again after a preamplifier output signal amplification, and finally get to facilitate measurement signal, and makes the signal forming, achieve the purpose of accurate measurement and analysis, spectrometer amplifier is of the components of the main amplifier. As a result, spectrometer amplifiers play an important role in amplifiers and nuclear detection. In this paper, we study a spectral instrument amplifier with a time constant of 10us. First introduce the basic principle of amplifier and the basic requirement of the design results, and on every part of the amplifier to carry on the design and research, in the master spectrometer amplifier, on the basis of various parameters influencing factors of preamplifier circuit, pole zero cancellation circuit, filter forming preliminary circuit principle diagram design, through software after NI Multisim circuit simulation, the simulation results, according to the simulation results further verify the circuit meet the design requirements, repeated adjustment circuit connection and circuit parameters, finally get a meet the requirements of the spectrometer amplifier.

Keywords

Nuclear electronics, Spectrometer amplifier, 10us, Filter forming, NI Multisim software simulation.

1. Introduction

1.1. Introduction

Nuclear electronics was formed in the middle of the last century, during which nuclear technology, high-energy physics, and detector-detecting particle count were studied. From the discovery of the initial radiation phenomenon, through the development of atomic bomb explosion, radiation detector, the development of scintillation detector, the birth of nuclear electronics name, the development of semiconductor detector, the invention of all-electron detector, the application of computer field finally developed to the present stage. The development of nuclear electronics has developed very rapidly during this period. The main purpose of the development is to fill in the shortcomings of the development of nuclear science.

In this process, nuclear electronics also draws lessons from many other fields of knowledge. In its development process also contributed to other fields of their own strength. For example, the technology related to the measurement of output waveform time and amplitude developed in the development of nuclear detection has helped the development of radar and computer in the middle of the last century. At present, the technology of converting analog signal and digital signal is also established in the development of nuclear electronics.

2. Theoretical Understanding and Analysis of Amplifiers

2.1. Basic Information on Radiation Detectors

A nuclear radiation detector is an element for nuclear radiation detection using ionization effects, luminescence phenomena, physical or chemical changes caused by nuclear radiation in gases, liquids or solids[3] There are usually two modes of signal output in a detector, one in the form of a waveform, which is called an electrical signal, the other is a signal that is not output in the form of an electrical signal, which is called a non-electrical signal, in which the former is more commonly used, because it can be further amplified, processed and analyzed and then used in various different situations in the laboratory, which is consistent with the results expected in this experiment, so this experiment also studies the detector that gives the signal as an electrical signal.

2.2. Preamplifier

The amplifier is usually divided into preamplifier and main amplifier. The preamplifier is placed around the detector or connected to the detector. Its input matches the detector. Because the position operator of the measured signal is not easy to enter at some times, it usually needs to be collected far away by cable connection, so that the external interference with the collected signal is greatly increased. The amplifier is designed to reduce the loss of the signal before the detector part and the back end amplifier, and to increase the ratio of the signal to the noise. The preamplifier is the device that plays this role, and it is usually placed in the detector. The

2.3. Main amplifier

The preamplifier is used as a component of the front end of the amplifier to adjust the input waveform by small amplitude, so that the detector and amplifier can cooperate better. The output waveform is not ideal in volt value and wave shape. Considering these bad effects, The waveform of the front amplifier needs to be processed again, which keeps the signal carrying information not lost, which requires the amplifier design very high. This task of reprocessing preamplifier output signals is usually done by master amplifier.

2.4. Filter Formulator in Amplifier

2.4.1 Function of Filter Forming Circuit in Spectrometer Amplifier

It has been known from the previous analysis that the main function of the filter forming circuit is to process the signal transmitted from the previous stage, to minimize the useless noise part of the signal and to change the waveform of the signal in order to obtain the best signal-to-noise ratio.

Filter related circuits are called filter forming circuits. The filter has both amplitude response and spectrum response. In time domain, it determines the appearance of the output waveform, and in the spectrum it removes the noise part of the signal, so the filter used to increase the ratio of signal to noise is also the forming circuit of the signal, so the filter is called the filter forming circuit.

2.4.2 Two kinds of information distortion in filter forming circuit

In the measurement of nuclear signals, the detection instrument usually outputs in the form of charge, and the size of the charge should maintain a certain linear relationship with the kinetic

energy carried by the measured ray, that is, the two need to be proportional. The better the proportional relationship, the more accurate the measurement of rays. It has been mentioned earlier that the change of the counting rate of the measuring instrument will change the value of the output waveform, and the interference of the outside world and the instrument itself will also change the size of the output pulse. None of these cases will cause the loss of some measured ray information and make the measurement results inaccurate. The signal obtained after the adverse effects of external conditions and interference in the design of the instrument is called distorted signal.

3. Spectrometer Amplifier Research and Design

After the previous discussion, we have a certain understanding of the structure, composition and evaluation index of the amplifier. Next, this experiment hopes to design the spectrometer amplifier on the basis of theoretical knowledge until the design results meet certain theoretical requirements. The specific design process and results will be discussed in this chapter.

3.1. Discussion on Filtering Forming Amplifier

In the discussion of the best filter, it is pointed out that the ratio of signal to noise determines the quality of the filter, and the waveform corresponding to the best signal-to-noise ratio is an infinite wide-tip pulse, as shown in the left figure 3-3. However, in practice, this waveform is not suitable for subsequent circuit measurement. According to the above analysis, in order to meet the requirement of high counting rate, the pulse width of output waveform should be reduced as much as possible. Gao Si pulse and infinite wide tip pulse tend to be almost the same in shape, and it can be found that the pulse width of Gao Si waveform is much smaller.

So can the waveform output from this experiment be changed into such a Gao Si or Gao Si-like waveform? If so, the output waveform can not only have a high signal-to-noise ratio, but also not a very serious waveform accumulation under the condition of high counting rate. Referring to the data RC it is found that the integral circuit can change the exponential descending signal into a Gao Si waveform. The circuit after CR differential and RC integration is called a filter forming circuit. The filter forming circuit is analyzed below to obtain a better shape of the output waveform.

4. Simulation Design of Spectrometer Amplifier

By understanding and understanding the components of the amplifier, the overall framework of the amplifier has been designed. In the following NI Multisim, the designed circuit is simulated by the corresponding modules. The parameters and circuit structure are adjusted on the basis of simulation to obtain the optimal results.

4.1. CR Discussion on Simulation Design of Differential Circuit

The following differential circuits are designed for differential time constants:
 $10\mu s = RC = 10\Omega \times 1\mu F$

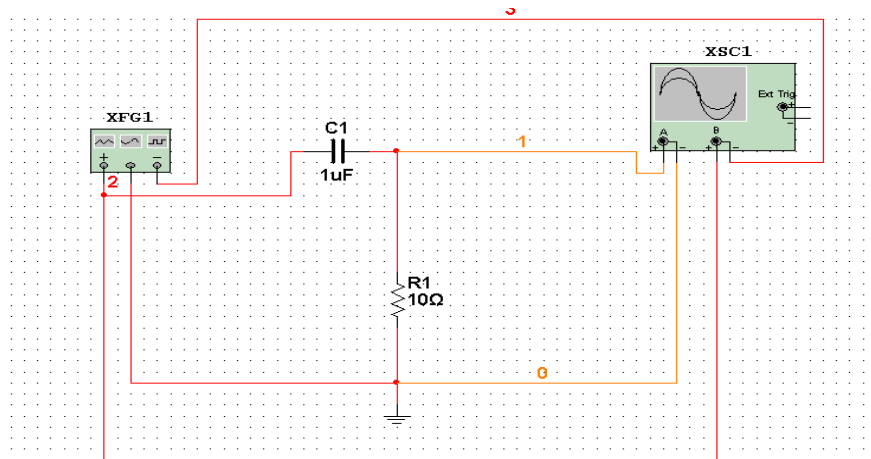


Figure 1.

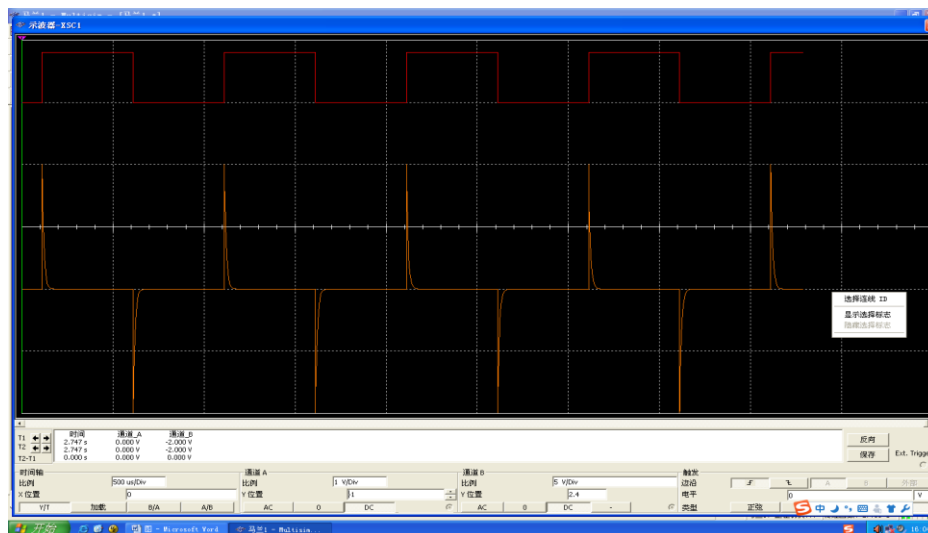


Figure 2.

The time constant of the CR differential circuit is 10 us, the upper waveform is the input step signal of one channel and the next waveform is the output waveform of two channels. After the step signal passes through the CR differential circuit, the output signal is exponential signal, and the polarity of the exponential signal corresponds to the input signal. Because the step signal is input, the waveform after passing through the differential circuit has no downpunching signal, so the pole-zero elimination circuit is no longer simulated in the simulation process. In addition, because the output pulse amplitude after passing through the differential circuit is small, in order to be easy to observe, the output waveform in the above figure is the amplified output waveform. For signal amplification, amplifiers are usually used to achieve the corresponding purpose. The following section will be analyzed and designed.

4.2. Design of Amplifier in Filtering Forming Circuit

According to the previous simulation results, it can be found that the amplitude of the output waveform after the original circuit decreases accordingly according to the different conditions. Therefore, we need to amplify the signal, which plays a role in further amplifying the signal in the circuit. The amplifier section consists of a feedback circuit and an operational amplifier. From the function of the amplification section, we can know that the selection of the amplification section will have a great impact on the amplifier index, so it is very necessary to select a good amplification section.

The magnification, linearity and stability of the amplifier, overload performance and rising time all determine the amplifier itself.

4.3. $(CR)_2 - (RC)_n$ Circuit Simulation Discussion

On the basis of the above, the filter forming circuit of the first class differential circuit with the same specification is added after the end of the total circuit. The simulation results are as follows:

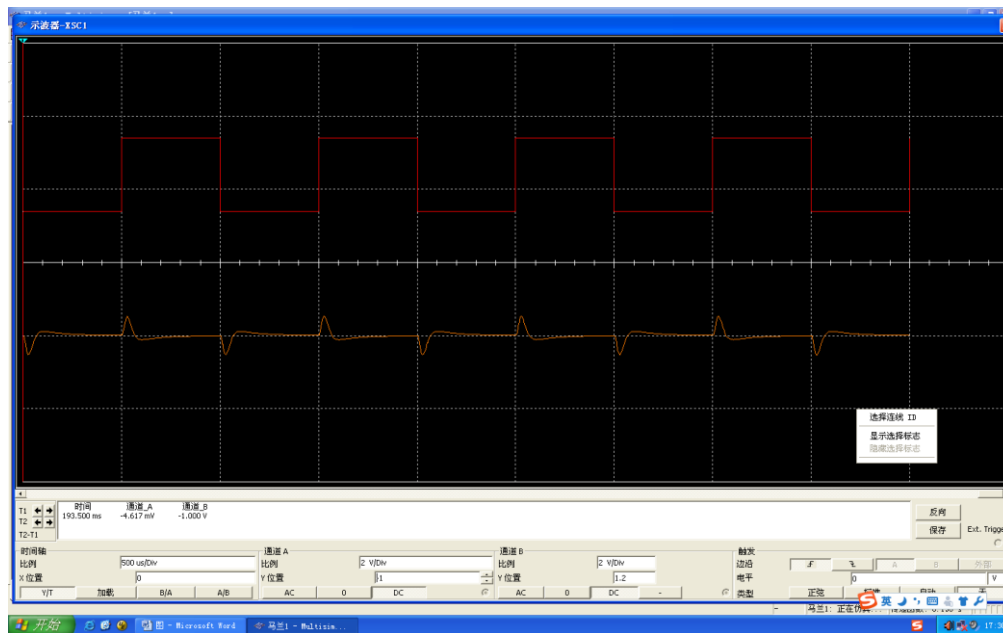


Figure 3.

$(CR)^2 - (RC)^4$ $(CR) - (RC)^4$ As can be seen from figure 3 above, the original output unipolar pulse signal has changed into bipolar signal after another differential, and the amplitude of the output pulse is greatly reduced, even smaller than that of the input step signal. In addition, it can be seen that the top of the waveform is sharp and the ballistic loss is large, which will reduce the measurement accuracy of the rear analyzer. It can be found that the signal-to-noise ratio of bipolar filter forming circuit is worse than that of unipolar filter forming circuit, but the baseline offset and fluctuation of the output waveform of the former are smaller. The waveform with better energy resolution can still be obtained under the condition of high counting rate. On the basis of the above analysis, we can draw the following conclusions for the selection of circuits: if the measuring equipment requires a high counting rate, consider using two CR circuits and take measures to reduce the pulse width to reduce the baseline offset and fluctuation; If the measuring equipment does not require a high technical rate, a CR circuit pulse can be used.

5. Chapter Conclusions

In the experiment of more than three months, from the initial reference to the data to the final conclusion, from the initial understanding of the amplifier to the later in-depth understanding of the principles of the learning amplifier and design, Finally, the design results were obtained successfully and the paper was written. This design is carried out from four aspects: understanding the background of the amplifier, putting forward the idea, understanding the function and composition of the amplifier, preliminary design of the amplifier and improvement design of simulation. Here is a section on each part of the design.

The first chapter is the introduction. After introducing the current situation and research background of spectrometer amplifier, this paper probes into the purpose and significance of spectrometer amplifier research, and discusses the contents of this experiment, and formulates the corresponding research steps and design requirements according to the actual situation. This chapter is more concise and clear.

The second chapter of this paper is a summary of the classification, composition, function and influencing factors of the amplifier after consulting many literatures and books on the spectrometer amplifier. To design a good spectrometer amplifier, we first need to know what its evaluation index is, and we need to know how to make the evaluation result of the design result better, all of which need to be completed on a certain theoretical basis. So this chapter makes a comprehensive introduction to the amplifier. The first is the need of the experiment, and the second is to make the reader more direct and convenient to be familiar with the amplifier, without the need to review the data again.

The third chapter of this chapter mainly introduces the preliminary design of spectrometer amplifier on the basis of certain theory, which includes the design of stage-zero elimination circuit and filter forming circuit. In addition, the requirements of the subsequent circuit are discussed, and what kind of output waveform is beneficial to the subsequent circuit. On this basis, the preliminary circuit schematic diagram is obtained.

The fourth chapter of this chapter is the simulation of the circuit diagram designed before. On the one hand, the purpose of the simulation is to better verify whether the circuit schematic diagram designed according to the theoretical knowledge is consistent with the theory. On the other hand, the optimal results are obtained by modifying the circuit schematic diagram according to the simulation results.

According to the above statement, the experimental conclusions can be summarized as follows:

- (1) The circuit designed in this experiment consists of CR differential circuit, pole-zero elimination circuit, amplifier circuit and four-stage RC integral circuit in series.
- (2) Both integral and differential time constants are set at 10 us, where the resistance is capacitance. $10\Omega \ 1\mu F \ 10\mu s = RC = 10\Omega \times 1\mu F$
- (3) The gain of a single amplification node is 2.
- (4) Under the condition of different counting rate, the circuit diagram can be adjusted, and the first class differential circuit can be added at the end of the original circuit at higher counting rate.

At this point, all the design work is completed, and the design results meet the design requirements, that is, the design of 10 us filter forming circuit is completed.

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