Design of Ultra-low Noise Power System for High-precision Detectors

Jian-min Wang, Hong-fei Zhang, Sheng-zhao Lin, Yi Feng, Dong-xu Yang, Jian WANG, Senior Member, IEEE

### Power Supply and RMS Noise

<table>
<thead>
<tr>
<th>Power Voltage</th>
<th>RMS Noise</th>
</tr>
</thead>
<tbody>
<tr>
<td>+17V</td>
<td>64.8 μV</td>
</tr>
<tr>
<td>-17V</td>
<td>66.8 μV</td>
</tr>
<tr>
<td>+5V</td>
<td>40.7 μV</td>
</tr>
<tr>
<td>-5V</td>
<td>40.7 μV</td>
</tr>
<tr>
<td>+33V (Bias Power)</td>
<td>31.0 μV</td>
</tr>
</tbody>
</table>
Design of ultra-low noise power system for high-precision detectors

Jian-min Wang, Hong-fei Zhang, Sheng-zhao Lin, Yi Feng, Dong-xu Yang, Jian WANG*  
(State Key Laboratory of Technologies of Particle Detection and Electronics, Modern Physics Department, University of Science and Technology of China, Hefei, Anhui, 230026)  
*Email: wangjian@ustc.edu.cn, IEEE Senior Member

1. Introduction

Scientific CCD detector systems are widely used in many areas such as high-energy physics, nuclear physics and astronomy for its high quantum efficiency and low readout noise. For example, some experiments use a low-noise CCD imaging, dark matter search based on the balloon-borne astrophysical cosmic-ray imaging, infrared CCD cameras could benefit from ultra low noise instead of scientific CCD systems. The horizontal structure of our scientific CCD detector system developed for Antarctica is shown in Fig. 1. The Low Noise Power module supplies power for each part of the system, especially supplies ultra-low noise power for the Cock and Stassinopoulos module and the Siemen Sensor Interface module. Its performance will influence the performance of whole CCD detector system.

2. System Design

Forward-electronic (FEE) of the detector system is generated. The FEE mainly consists of the clocks and biases circuit for driving the CCD, the CCD signal processing circuit and ADC circuit for sampling the CCD output. The power noise of the biases circuit and the CCD signal processing circuit need to be under 60μV rms. The power noise of the biases circuit could be a little higher as about 100μV rms. The third part is the digital controlling circuit including FPGA, digital chip and USB Interface, etc. The power noise requirement of which is about 400μV rms max. The power supply structure of the CCD detector system is shown in Fig. 2.

3. Power Generation and Filtering

In the power system a 24V power supply is used. SC-DC power controllers are used to generate multi-channel voltages. The entire conversion operating is very high in this case and it's convenient to convert the 24V to multivoltage of system requirement. But the power noise of the DC-DC devices is usually as high as 100μVrms, so it's much higher than the demand of the ultra-low noise power. Thus it is necessary to use multi-channel filters to absorb the ripple and use low dropout regulator (LDO) which has very low output noise.

When the power generated by LDO is transferred to the MB from the PIU and to the MB from the NB through connectors. Filter circuits are used once more to filter the noise as low as possible. The Fig. 3 shows the structure of the power generating for the 24V power input to the multichannel filters.

4. Test

The temperature environment is shown in Fig. 4. The noise of each channel of the power system has been tested. The result is shown in Table 1.

In order to know the power stability of the detector system, a spectrum analyzer was used to measure the noise spectrum as shown in Fig. 5. Additionally, in order to test the temperature environment, a refrigerator was used to simulate the temperature environment as low as -104K is used to test the output voltage of the power system. The result shows that the output voltage of the power system is normal and stable. The Fig. 6 shows the ±24V voltage change with temperature range from 203K to 193K.

Fig. 4: The block diagram of the power generating and filters of the power system

*Fig. 4 shows the block diagram of the power system. The power is generated from a 24V DC input and filtered by the power supply unit (PSU) to provide stable power to the detector system. The filters are designed to reduce noise and improve power quality.

Fig. 5: Power noise spectra

*Fig. 5 shows the power noise spectra measured at various power supplies. The noise is measured over a range of frequencies and shows the stability of the power system.

Fig. 6: Output voltage change with temperature

*Fig. 6 demonstrates the change in output voltage of the power system as a function of temperature. The results indicate that the output voltage remains stable across the temperature range tested.

Bibliography