DESIGN, IMPLEMENTATION AND SETUP OF THE FAST PROTECTION SYSTEM FOR CSNS *

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Abstract

The China Spallation Neutron Source (CSNS) [1, 2] is being constructed in Dongguan, Guangdong Province, China. The first proton pulse will hit on the target in March, 2018 as planned. CSNS is a large neutron beam research facility with a proton beam power of 100 kW. Three neutron instruments are being constructed for the first stage, with another 17 to be built later. The Fast Protection System (FPS) is one of the key systems to prevent the accelerator components along the proton beams from being damaged. Design, implementation, setup and tests of the FPS are introduced in this paper.

INTRODUCTION

As the other high power accelerators in the world, components along the proton beam will possibly be damaged by a mis-steering beam, especially for the DTL (Drift Tube LINAC) cells. Another issue is the post irradiation due to the beam loss, which should be controlled strictly below 1 W/m for hand maintenance [3, 4]. A Fast Protection System (FPS) with a response time of around 10 μs is strongly needed. A self-designed FPS has been developed and preliminary tests has been brought out. Till now, most of the signals from the power supplies and beam loss monitors along the linear accelerator are collected by the Fast Protection System.

DESIGN AND IMPLEMENTATION OF THE FPS FOR CSNS

FPGA is chosen as the base of the design since its flexibility and fast response time. High speed serial transmission technique is used to reduce the number of connections tremendously. A 6U standard VME crate is used to ease the maintenance and upgrade, and to improve the reliability and scalability. Figure 1 shows the distribution of the FPS.

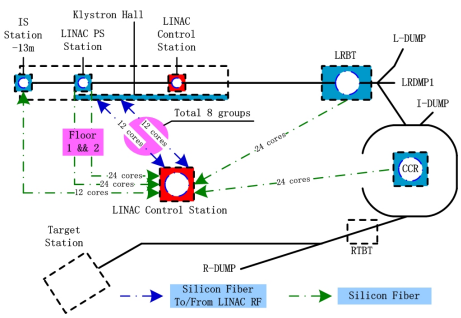

Figure 1: Distribution of the FPS.

Figure 2 shows the structure of the FPS.

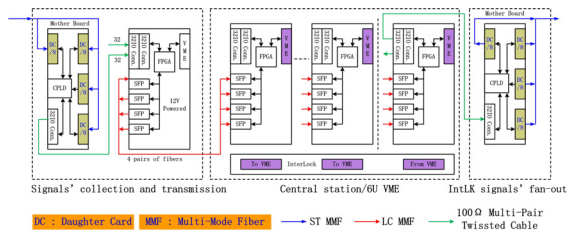

Figure 2: Structure of the FPS.

Signals collection are done locally near the interlock sources, and then transmitted to the central station via high speed serial optical links. Total 16 signals are carried with one pair of fibers. The high speed serial link are implemented with the Rocket I/Os of the XC6SLX100T-3FGG900 from Xilinx and optical transceivers. A dedicated auto-sync logic has been developed for the serial link to work when both fibers of the same link are plugged into the optical transceivers under normal conditions.

Figure 3 shows the picture of the main board. Either VME +5V or external +12V can be used to power the board.

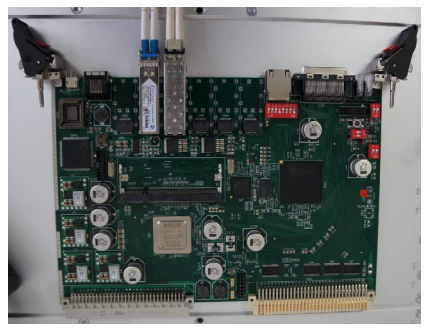

Figure 3: Picture of the main board of FPS.

To improve the overall reliability, a real-time heart-beat function is used for each input signal. That is, heart-beat signals are generated at the collection part, and then checked in the main boards at the central station. A width of 100ns is defined for the heart-beat signals in our case, see Fig. 4.

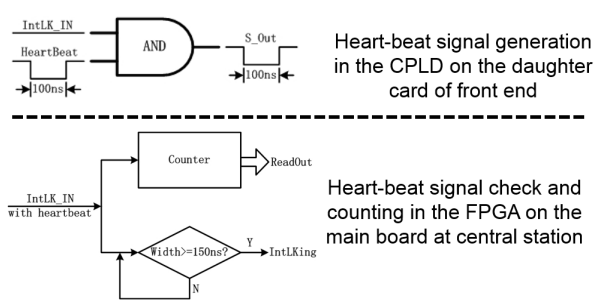

Figure 4: Illustration of the heart-beat function.

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The Bit error rate for the high speed serial link has been tested with no errors for a period of 27 hours for two links. Figure 5 shows the scheme for bit error rate test.

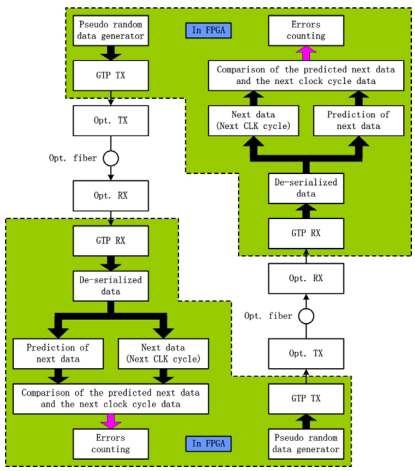

Figure 5: Scheme of the bit error rate test.

Figure 6 shows the field photos of the central station and one of the local stations of the FPS.

Figure 6: Photos of the central station and one of the local stations of the FPS.

FIELD TESTS OF THE FPS

Interlocking functions and heart-beat functions were tested first with all functions ok. Time consumption has been measured thoroughly since the critical requirement. Figure 7 shows the critical paths for the FPS. Delay of cables and fibers contribute mainly.

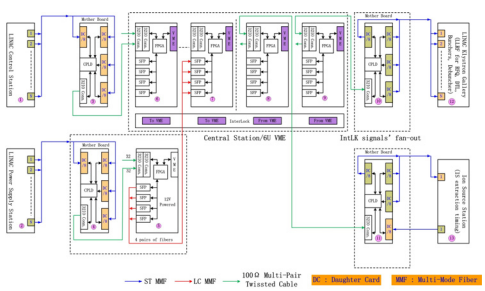

Figure 7: Illustration of critical paths for the FPS.

For the high speed serial link with no fibers, the delay is around 230ns. All delays of the parts on the route from interlock inputs to outputs are tested. Total delay from the inputs to stop the RFQ power is around 1.8 μs, and that to stop the extraction timing of the ion source is around 2.4 μs. For power supplies, response time of themselves is between 2.8 μs to 3.4 μs. So, the total response time is no more than 5.2 μs to stop the RFQ power, and no more than 5.8 μs to stop the extraction timing of the ion source. For the beam loss monitors, the response time of themselves is defined as 10 μs with a compromise among noises, cosmic rays and real loss signals, so, total response time is no more than 11.8 μs to stop the RFQ power, and no more than 12.4 μs to stop the extraction timing of the ion source.

Further tests will be brought out with the equipment and proton beams later.

SUMMARY

A Fast Protection System for CSNS has been developed and setup. FPGA and high speed serial transmission technique is used for a fast and compact design. Heart-beat function is implemented to improve the overall reliability. Function tests and time consumption tests have been done, results of which show that the system can fulfill the requirement well. Further tests will be done according to the construction procedure.

REFERENCES

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