NSLSII PHOTON BEAM POSITION MONITOR ELECTRONICS TESTING AND RESULTS

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Abstract

Simulated and real beam data has been taken using the new NSLSII Photon BPM electronics. The electrometer design can measure currents as low as 10’s of nanoamps and has an ability to measure a current as high as 300mA. The 4 channel design allows for internal calibration and has both a Negative and Positive bias ability. Preliminary bench testing results has shown excellent resolution.

INTRODUCTION

At NSLSII we have installed a 4 blade design X-ray beam position chamber. The focus of this paper will be on the electronics and tests performed in the lab and with beam using diamond detectors installed @ NSLS beamlines. The design requirements of the electronics were to measure beam currents from 500nA to 1mA. With the Blade Chamber design, signals levels we could expect, were to be in this range. The electronics also required both a positive and negative Bias. The blade current transfer function reveals that without bias we would see ~ 0.5ua for every 1ma of stored beam. This number would double with a bias present. A block diagram is shown in Fig 1. The electronics were designed with the same idea of a AFE (Analog Front End) and a DFE(Digital Front End). As shown in - Fig. 2. This allowed the design to move forward quicker, utilizing what was done with the NSLSII RF BPM. The initial testing used the exact same DFE as the RF BPM electronics, but have since evolved and a new DFE was designed using the ZYNQ FPGA. The electronics PC boards also used the same chassis as the RF BPM.

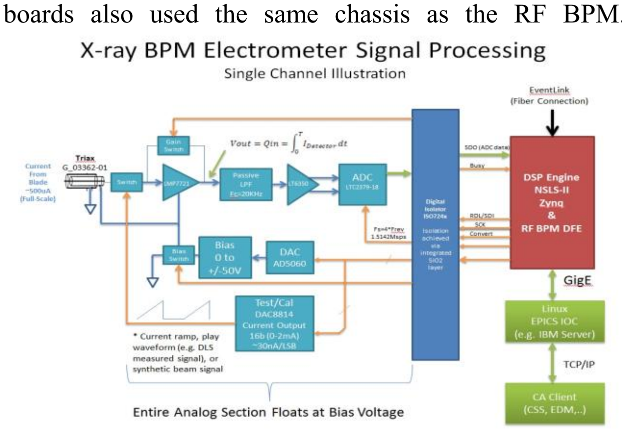

Figure 1: Block diagram of AFE/DFE.

ANALOG ELECTRONICS

The Analog Front End (AFE) was designed as a 4 channel electrometer. The first stage of the design required converting the current into a voltage. The lowest bias current amplifier in the industry was selected as the transimpedance front end. Because of the wide dynamic range mentioned previously 5 gain stages were developed. For the most sensitive gain stage, a range of 10’s of nanoamps to 1uA was developed. The other gain stages are 1uA – 10uA, 10uA – 100uA, 100uA -1.2mA and a high gain stage 1mA – 250mA. The switching of the gain stage is done with a very low resistive CMOS switch. A reset switch was also included to discharge the signal before taking a fresh measurement. A simple two pole anti aliasing filter was also included before the digitizer. The digitizer chosen, was a 18bit 1.6Mhz serial device however, a new 20bit version has come out, which has the same footprint and would only require a small software change. Because a Bias was also required we decided to float our entire receiver section. This involved isolators for all signals coming in and out of the receiver. The bias was limited to less than 50V for safety reasons. We ensure that the voltage cannot exceed this by two means. One, our Bias supply control signal is set by a DAC. The reference for this DAC was limited to limit the output to 43V. A 43V Zener diode was also added to provide additional protection. The Xbpm chamber also has a provision for an additional “Electrode”. Because of this, the design was modified to allow a bias to also be present on that plate as well. The board also has a provision for on board calibration using a 4 channel 14bit current DAC which allows for testing currents from 100nA to 1.5mA.

Figure 2: AFE and DFE connected together.

To determine what our signal might look like from the blades, a trip to the Diamond Light Source (DLS) was done. Beam current was very similar to what we would see here at NSLSII (250-300mA). With that current we measured a blade current of 60uA. DLS runs without bias on XBPM blades, causes factor of 2 decrease in signal level from ~ 500ua to 250uA. This is still plenty of signal to obtain a few 10's nanometer resolution at 100- 200Hz processing bandwidth. Looking at a single blade signal directly into a 40Gsps scope terminated into 50ohms, the scope was also band-limited to 1Ghz. We observed that most of the blade signal was "DC" (Fig. 3). Because of these results, most of the testing was done with DC current or pulses. However, Sine and Square wave measurements were also performed.

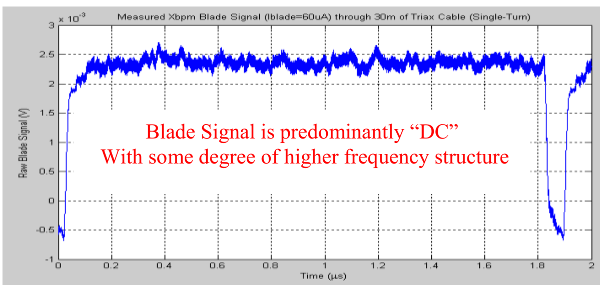

Figure 3: Temporal Blade Signal over 1-turn from Diamond Light source.

LAB TESTING

To prepare for our lab testing a Keithley current source was purchased (model 6621). This model had enough dynamic range to test the full range of our electronics. Also this model would allow both pulse and sweep measurements. These tests would be repeated using the on board current DAC as well. With the 18bit digitizer we had a full scale of ~260k counts. Next step was converting the counts to current for calibration. Our gain stages typically were set up for 0-2.5V out, this equated to 25,000 counts per nanoamp. Starting with the most sensitive gain stage (500nA)We quickly found that our electronics greatly outperformed our design requirements. Our noise floor was -120 dB which allowed us to resolve 10's of nanoamps. Of course at those low currents the resolution would be degraded. Because of the extreme sensitivity we were also able to measure the noise floor of our current DAC. Even with the DAC set to "zero" we would still record 50-60nA. The accuracy and linearity at each gain stage was measured as well as channel to channel coupling. We could not detect any coupling channel to channel with DC and pulse measurements. The error in the measured current compared to actual was less than 1% (Fig. 4) for each gain stage except at the upper and lower limits. Various DC levels were examined along the full range of the electronics. Test data confirmed that data was linear along the data range unless it was taken at the highest or lowest gain stage. To ensure that one would never be in a non-linear range a gain switch would be required.

1 Ua Gain stage		counts /.1uA	ave error
DC current in	digitizer counts		
20nA	-122460	2260	10%
100nA	-103600	25000	0.01%
200nA	-78540	25000	0.01%
400nA	-28440	25000	0.01%
500nA	3460	25000	0.01%
1uA	129300	24000	4%
10uA Gain stage			
1uA	-100900	25000	0.01%
2uA	-75800	25000	0.01%
3uA	-50850	25000	0.01%
10uA	129200	24000	4%
1mA Gain Stage			
.1mA	-103650	22000	0.01%
.2mA	-81650	22000	0.01%
.3mA	-59650	22000	0.01%
.4mA	-37670	22000	0.01%
.6mA	6325	21980	0.01%
1mA	94250	21990	0.01%

Figure 4: Data taken during lab measurements.

BEAM TESTING X28 (NSLS)

Because we don't have our Xray beam lines ready for beam, an alternate beam line for testing was necessary. Fortunately for us here at BNL we still have an active light source at NSLSI. We were given the opportunity to test our electronics on one of the Xray beam lines (X28). The only concern was that detector that we were going to use to get our signal was a Diamond Detector rather than a Blade design. Signal levels were expected to be much larger than we would like. Using filters to bring the signal into our range was done and currents in the 100's of nanoamps were measured. Using the most sensitive gain setting, the results looked very promising however, results showed 3khz component. A possible explanation is the pinhole aperture and the diamond detector were not mounted together, so this component was likely due to relative movement between them. (Fig.5) The Diamond detector was moved relative to the beam in 100um steps from -300um to +300um. First in vertical, then in horizontal. ADC data for the 4 channels was recorded. The sampling rate was 378khz and record length was 32k samples. Sensitivity plots were done to find Kx, Ky. Position plots showed very good correlation compared to motor movements.(Fig. 6)

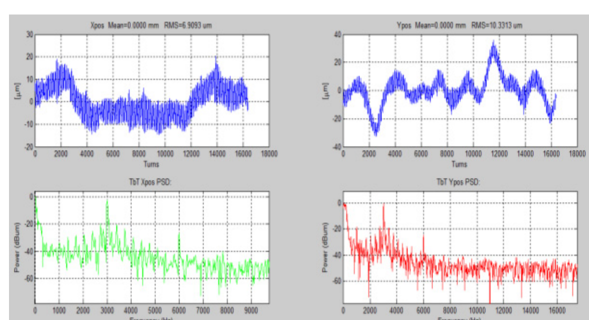

Figure 5: Time domain plot and corresponding PSD sampled at 378khz.

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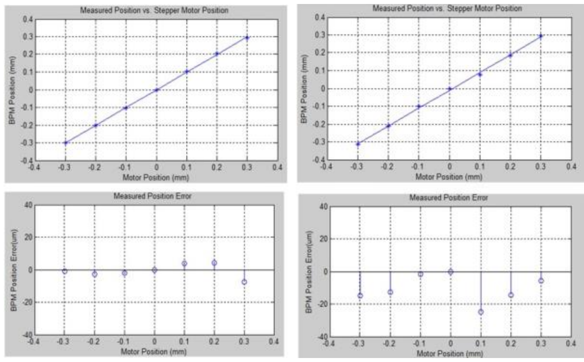

Figure 6: Using the Kx and Ky values computed, the difference over sum position calculation was scaled to mm and plotted.

BEAM TESTING X15 (NSLS)

Within less than one month after testing at X28 another beam line became available X15. This beam line was available for us to test our electronics as well as test other diamond detectors. Two types of diamond detectors were available (Fig. 7). We also knew that the mounting of those detectors was critical for us to take precise measurements. The mounting bracket was adjusted however, it did still create a concern with stability. The white beam tests taken at X15 also allowed us to test a "hotter" beam. Removing all the filters to try to measure the largest beam signal was done. Even with all filters removed the total beam current was still limited by the pin hole aperture which acted like a collimator. Still, we did measure currents in the 100's of micoamps. Numerous scans were done with both detectors to evaluate sensitivity of the detectors. As shown in - Fig. 8. The scans showed that with such a large beam (~350uA , 300um beam) only a small number of steps were achievable due to the aperture.

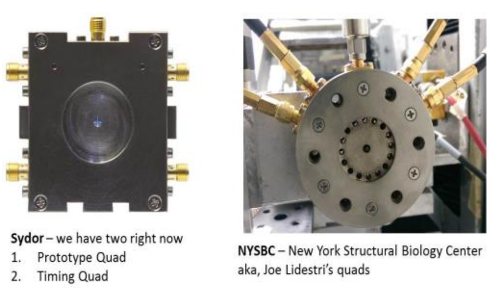

Figure 7: two types of diamond detectors used to test electronics.

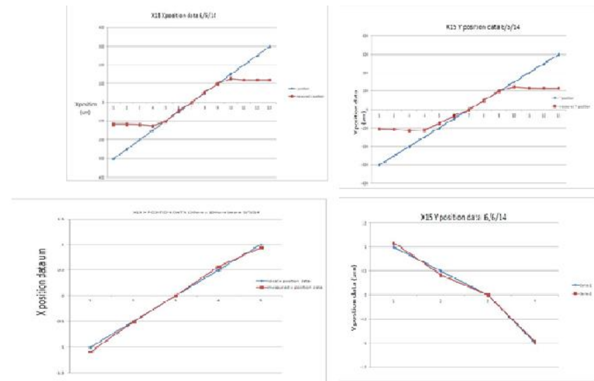

Figure 8: X and Y measurements done with both detectors.

CONCLUSION

The Photon Beam Position Monitor electronics have shown to perform very well in different beam conditions however, our beam results were done with a diamond detector not a blade emission design at NSLS. We expect confident that based on the results from beam testing and the lab results the electronics will perform as expected with the actual Xray chamber. The second revision of the design has just been completed and is undergoing testing now. The changes were very minor and based on bench tests I don't see any degradation in performance. The next step is to work on interfacing the electronics into the control network. Currently I am working on CSS pages as well as an IOC for the control. I look forward to testing on NSLSII.

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