FPGA DATA BLOCK FIFO FOR THE APS ID MEASUREMENT SYSTEM*

J. Z. Xu, R. Farnsworth, I. Vasserman
Advanced Photon Source, ANL, Argonne, IL 60439 USA

Abstract

A Hall probe insertion device (ID) measurement system has been developed to characterize the IDs at the Advanced Photon Source (APS). The system uses the latest state-of-the-art field-programmable gate array (FPGA) technology to synchronize the position and Hall voltage measurements. Data block first-in-first-out (FIFO) has been implemented to transfer the data from the FPGA to the host computer during measurement. The system is capable of continuous scanning measurements on a full 6-meter bench at 1 msec per data point with a position resolution of 1 micron and Hall voltage precision of 5-1/2 digits.

INTRODUCTION

Insertion devices (IDs) at the Advanced Photon Source (APS) are measured and fine-tuned against their design specifications at the magnetic measurement laboratory [1] before installation into the storage ring. The APS Hall probe measurement system is designed to measure the magnetic field distributions of the IDs. The system has been upgraded with the latest state-of-the-art field-programmable gate array (FPGA) technology to synchronize the measurements of position and Hall voltage.

Since the FPGA hardware has limited onboard memory capacities, data block FIFO has been implemented to transfer measurement data to the host computer efficiently during measurements. The new system is capable of continuous scanning measurements of the IDs at the speed of 20 cm/sec with a spatial resolution of 0.2 mm reliably.

SYSTEM DESCRIPTION

The Hall probe measurement system consists of the following subsystems shown in Figure 1.

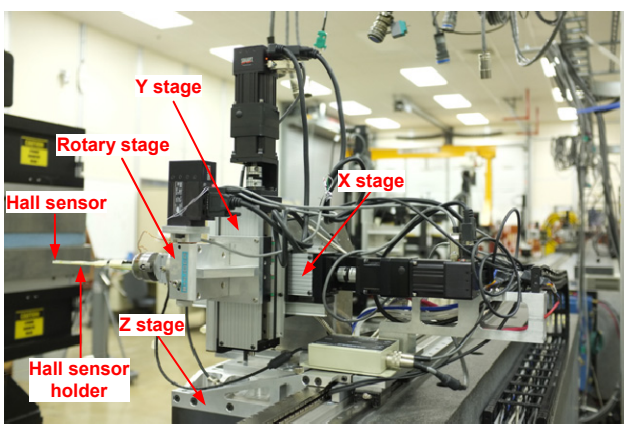

Figure 1: Hall probe measurement system.

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A rotary stage carries the Hall sensor holder. A two-axis (X and Y) linear stage with digital linear encoders supports the rotary stage. All the stages are remotely controlled by servo motors. A (Z) linear carriage with air bearings carries the stages as well as all the pre-amplifiers and electronics moving along the Z direction. The linear carriage is remotely controlled by a linear servo motor. A 7-meter-long granite table with a 6.8-meter linear digital encoder hosts the carriage as well as the cables and air tubes.

A high-precision Hall probe sensor is mounted on the sensor holder. A PXI shelf with a control card hosts the FPGA card and digital multimeter (DMM) card. Software programs are hosted on the control card.

SYSTEM CONTROL, DATA ACQUISITION, AND ANALYSIS

LabVIEW-based system software has been developed to coordinate the stage control and data acquisition. Figure 2 shows the schematic layout of the system control and data acquisition architecture. The system can be accessed via the Internet from anywhere at any time, wired or wireless, through the remote desktop interface.

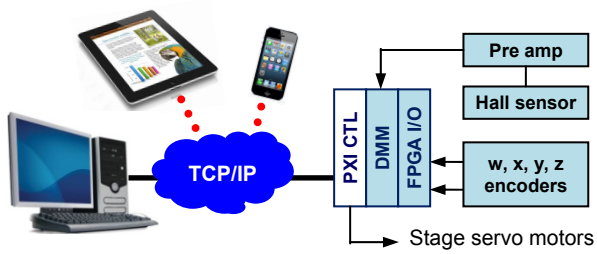

Figure 2: System control and data acquisition architecture schematic layout.

The system software sets the FPGA firmware to monitor the stage digital encoder positions and commands the stage scan across the measurement region. For each measurement point, the FPGA checks if the DMM is ready for measurement. If so, it trigs the DMM to take a Hall voltage measurement and records the position information to its memory; otherwise, it skips the position recording of that point. Once the DMM finishes the measurement, it will flag its state to the FPGA and wait for the next measurement trigger by the FPGA. All the above tasks are carried out on the fly. This approach guarantees that every Hall voltage measurement pairs with its position information no matter how fast the stage moves.

The FPGA onboard memory has been configured into three blocks for data block FIFO. Once the first block is full, a flag is set and the control card starts to read the data in the first block while the second block is recording,

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and so on so forth. The FPGA hardware executes all the tasks in parallel at the speed of 40 MHz. This method minimizes the data transfer overhead between the control card and the FPGA. It enables the system to carry out position scanning measurements over a speed of 50 cm/sec with a special resolution of one micron without range limit. The system is capable of scanning measurement in all X, Y, and Z directions. In order to achieve a field measurement precision of 0.05 Gauss, the DMM card has been configured with a measurement precision of 5-1/2 digits. Therefore, with the cross-backplane communications between the FPGA card and the DMM card, each Hall voltage measurement takes less than 1 msec to complete.

The Hall voltage is converted to a magnetic field with the Hall probe calibration data in real time. Once the measurement scan finishes along with the paired positions information, the data is recorded onto the non-volatile data storage of the control card. The field and the position are also displayed on the screen in real time. For ID measurements, a magnetic analysis module written in IDL carries out the data analysis to produce the first and second integrals as well as the phase errors and radiation brightness information of the ID.

MEASUREMENT RESULTS AND DISCUSSION

A typical APS ID magnetic field measurement taken with the Hall probe measurement system in the Z-direction is shown in Figure 3. It is displayed in the Hall probe magnetic field measurement analysis and plot module.

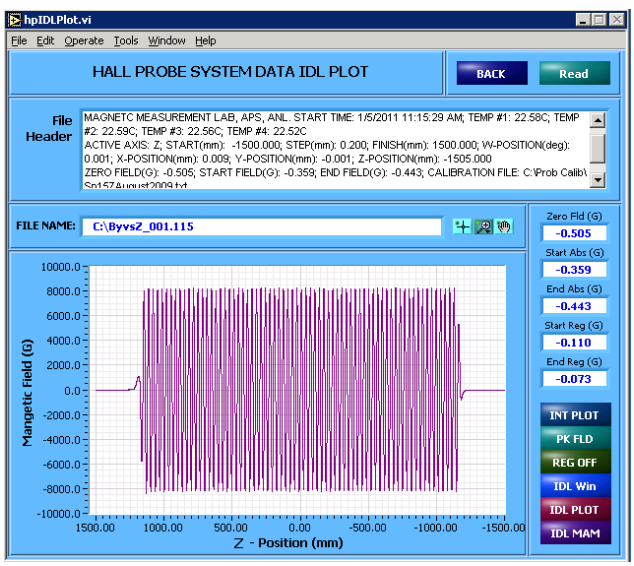

Figure 3: APS ID magnetic field measurements.

The precision of the DMM was set at 5-1/2 digits. The measurement scanning speed was set at 20 cm/sec. With a spatial resolution of 0.2 mm, no missing data points have been observed. It was a 2.4-meter-long ID, the measurement range was set for 3 meters. The parameters shown on the left side of Figure 3 are the field background calibrations. Total time for the scan is less than 30 seconds.

Much faster scanning speeds with much high spatial resolutions have been tested. The measurements yield missing data point pairs. Since the Hall voltage measurement pairs with its position information, no information was lost.

CONCLUSION

The Hall probe magnetic field measurement system has been upgraded, tested, and commissioned at the Advanced Photon Source. With the latest state-of-the-art FPGA technology and data block FIFO implementation, the new system is capable of continuous scanning measurements of the ID magnetic field at the speed of 20 cm/sec with a special resolution of 0.2 mm. The system measurement reproducibility is 0.05 Gauss.

REFERENCES

[1] L. Burkel, R. Dejus, J. Maines, J. O'Brien, J. Pflueger, I. Vasserman, "The Insertion Device Magnetic Measurement Facility: Prototype and Operational Procedures," ANL/APS/TB-12, March 1993.

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