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BETATRON TUNE MEASUREMENT SYSTEM UPGRADE AT NUCLOTRON

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A few improvements have been made in order to enhance the resolution of the Q measurement system such as development of the additional NI FlexRIO digitizer module with two 18-Bit ADC AD7960 and 90ps resolution time-to-digital converter TDC-GP22 for precision beam revolution frequency measurement. The new digitizer allows carrying out measurements during beam acceleration.

Keywords: Betatron tune, FlexRIO

1. General description

The core of the Q-measurement system [1] is control system based on PXI chassis (Figure 1). It contains digitizer module which is used to convert amplified signal from pick-up electrodes into digital representation. Windowing of the input signals, interpolation and FFT algorithms are implemented in the FPGA. The signal processing (FFT calculation) starts simultaneously with the start of the input data accumulation and ends at the same time with the end of the data accumulation. The resources of the PXI system controller (PXIe-8135) are used for distributed control system based on TANGO Controls software toolkit in which devices are controlled and monitored in a local distributed network. The signals from the two ADC channels and the FFT results are stored in the internal memory of the FPGA module. A FlexRIO digitizer module has direct access to the input-output ports of an FPGA.

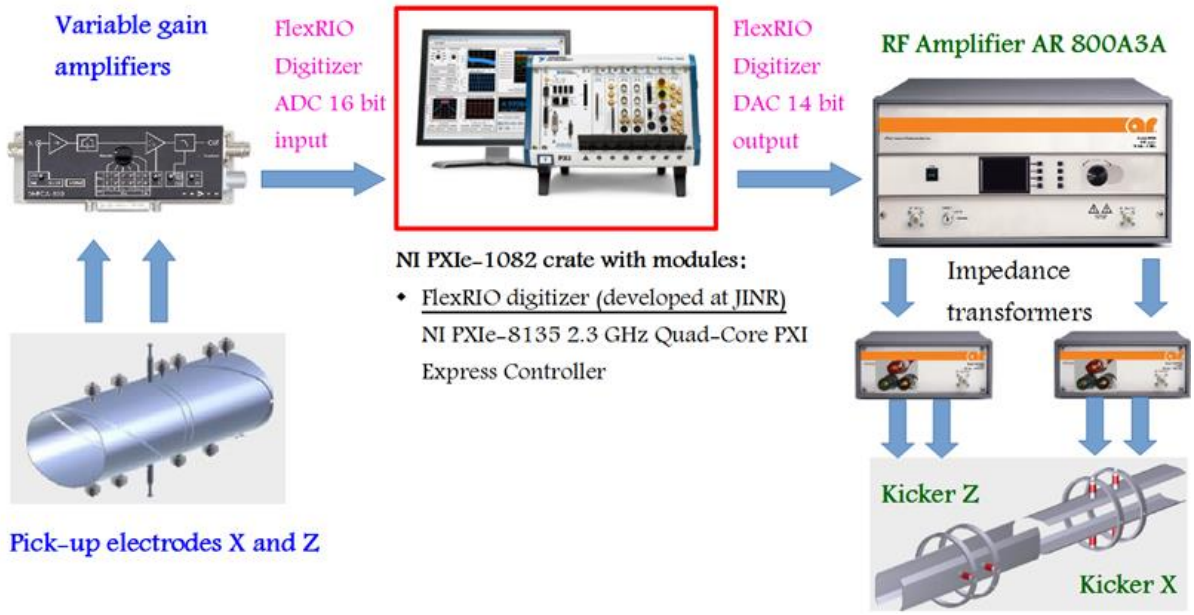

Figure 1. Q-measurement system

All components of digitizer module are controlled by FPGA logic, created with a help of LabView FPGA tool [2]. The connection of an FPGA module and digitizer is shown on the Figure 2.

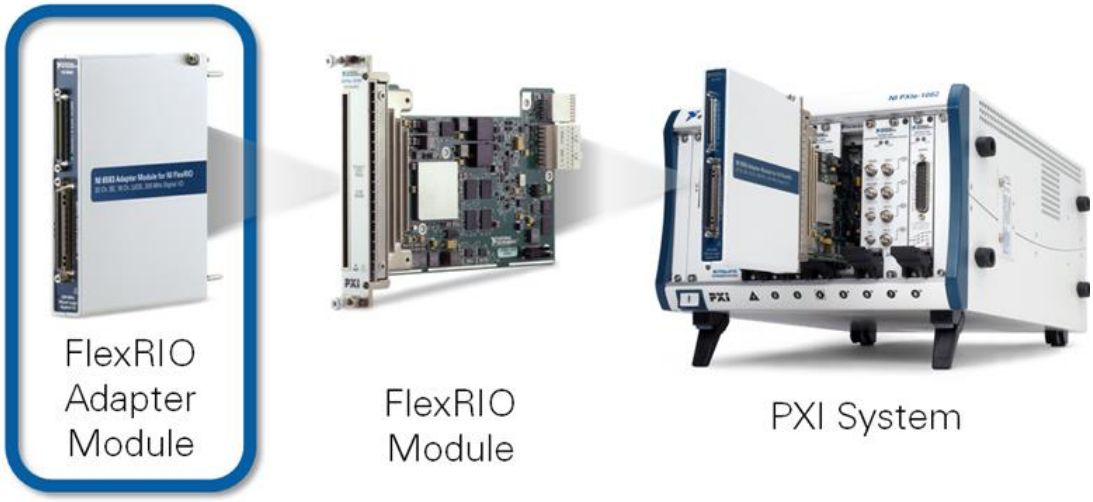

Figure 2. FPGA PXI module and FlexRIO digitizer

First developed 14-bit FlexRIO digitizer (Figure 3) was used for calculation of Q as the ratio of the betatron oscillation frequency (f_β) and the particle revolution frequency (f_{rev}): $Q = f_\beta / f_{rev}$. To increase accuracy and to be able to measure Q at low beam intensity a new 18 bit digitizer was developed.

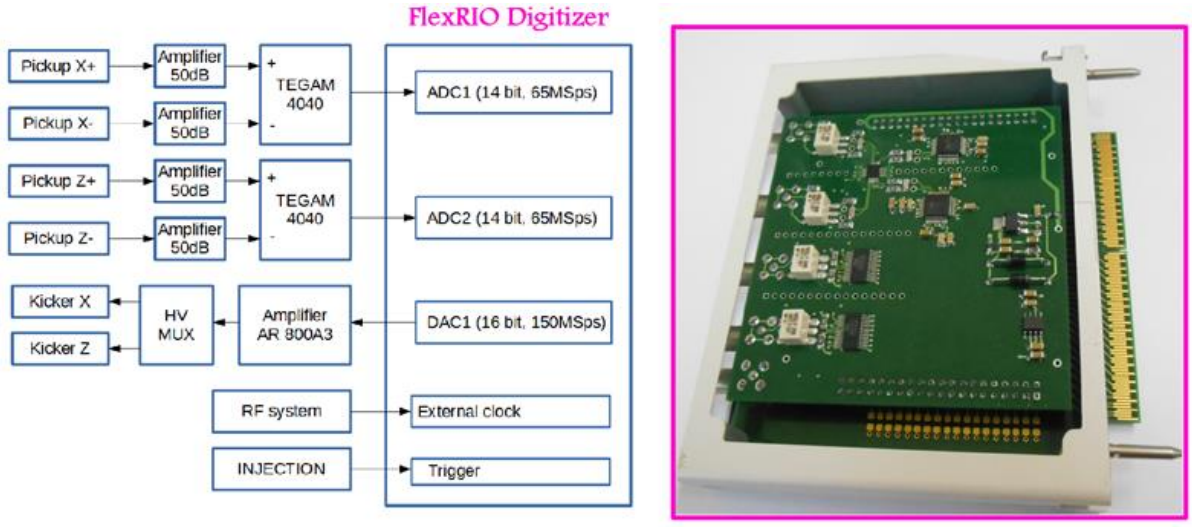

Figure 3. 14 bit FlexRIO digitizer

2. New digitizer overview

The new 18 bit FlexRIO digitizer module is a custom developed at JINR 8-layer PCB board which is compatible with NI PXIe-7976R PXI Express module. It has Kintex-7 XC7K410T FPGA onboard which calculates in a real time a high resolution FFT. The new digitizer module is shown on the Figure 4.

Figure 4. Digitizer module

To provide signals for FFT algorithm two 18 bits ADC are used. One ADC channel is used for Q_x measurement and the second one is used for Q_y. Each ADC is an 18-bit, 5 MSPS, charge redistribution successive approximation (SAR), analog-to-digital converter – AD7960. The AD7960 digital interface uses low voltage differential signaling (LVDS) to enable high data transfer rates and operates at a high frequency of 200 MHz which eliminates the need for anti-aliasing filters. A conversion can be initiated asynchronously to provide the ADC sampling with a beam revolution frequency. This approach simplifies and speed-up Q measurement because the resonance peak position obtained by the FFT represents the fractional part of *Q* with no additional computations.

To measure the exact value of the revolution frequency a high resolution time-to-digital converter is used – TDC-GP22. It can measure the period within 90 ps accuracy. To provide a low jitter and noise-free signal for TDC a very fast comparator with LVDS compatible output was used – ADCMP605. It has an adjustable hysteresis feature that significantly improves accuracy and stability and gives an opportunity to adjust comparator switch level.

An optically coupled high speed gate HCPL-2631 with propagation delay of 45 ns is used for synchronization with the start of injection to give a start for data accumulation. A high-speed 14-bit resolution DAC (DAC904) is used for an excitation signals generation (white noise and frequency scan) which are used to excite transversal beam oscillations.

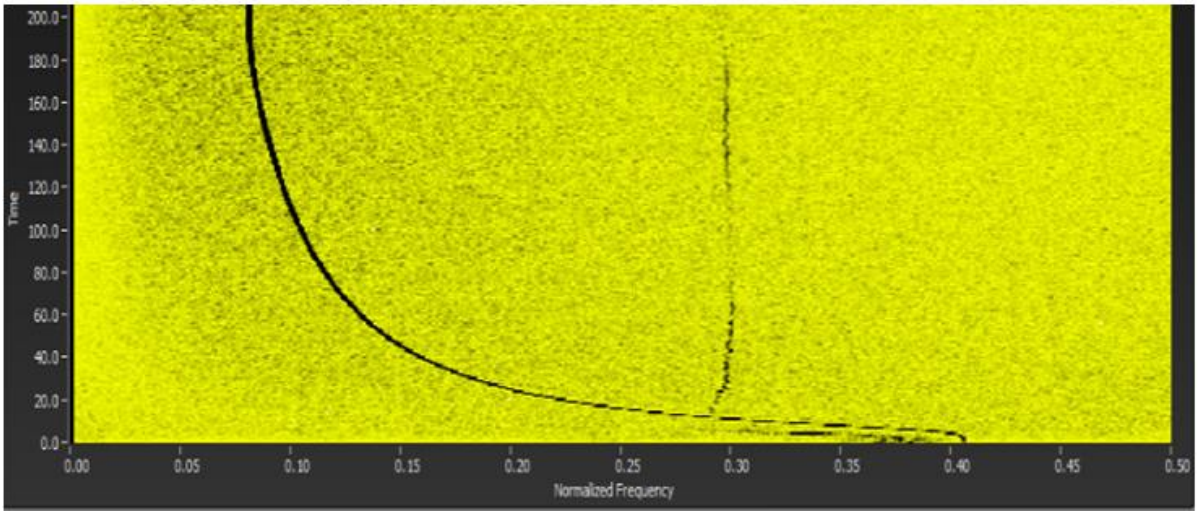

Figure 5. Q_x tracking during beam acceleration

3. Conclusion

The new 18 bit digitizer allows tracking the Q during acceleration cycle with low beam intensity 10^8 particles (Figure 5). New Q-measurement system is designed for measuring Q at compact superconducting synchrotrons with a beam revolution frequency up to 10 MHz, such as Booster and Nuclotron.

References

[1] *A.* Boccardi, M. Gasior, R. Jones, K. Kasinski, R.J. Steinhagen. The FPGA-based continuous FFT tune measurement system for the LHC and its test at the CERN SPS. European Organization for Nuclear Research, CERN – AB Department, CERN-AB-2007-062, Geneva, Switzerland, August 2007.

[2] NI LabVIEW FPGA Module: http://www.ni.com/labview/fpga

[3] NI FlexRIO FPGA module: http://www.ni.com/product-documentation/10800/en/