KEK ATF INTEGRATING CURRENT TRANSFORMER SIGNALS DATA ACQUISITION SYSTEM UPGRADE STATUS REPORT

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Abstract

KEK Accelerator Test Facility (ATF) has seven beam intensity monitors based on Integrating Current Transformers (ICTs) to measure a bunch charge and its transmission between the accelerator sections. These ICTs' signals acquisition system was based on the CAMAC Gated 12-bit ADC modules. These integrate the entire pulse within a width of an input gate signal. Typical gate signal width is 1 μs to share it with other analogue signals acquisition, while the ICT signal width is 150 ns. As a result, an additional noise is accumulated with a bunch charge. Also, CAMAC gated ADC module can accept only negative polarity signals. So, there is necessity to invert polarity of some ICT signals, as well as amplify it after the inversion. As a result, the bunch charge measurement resolution becomes 3 % (RMS). In order to improve the bunch charge and transmission measurement resolution, upgrade of the DAQ system based on the digitizer system has been done. The RedPitaya STEMlab 125-14 FPGA board was chosen as a digitizer development platform. This upgrade demonstrated two times better bunch charge and transmission measurement resolution than the previous system, and contributes to the improvement of ATF beam tuning.

INTRODUCTION

KEK Accelerator Test Facility (ATF) conducts beam instrumentation R&D for International Linear Collider (ILC) project. ATF includes 1.29 GeV normal conductive S-band Linac, Beam Transport (BT) line, Damping Ring (DR), Extraction (EXT) line and Final Focus (FF) beamline. In order to measure the beam intensity and its transmission between the accelerator sections, there are 7 beam intensity monitors. These are Integrating Current Transformers (ICTs) (see RF-Gun ICT photo on the Fig. 1). KEK ATF ICTs signals DAQ system was based on 12-bit CAMAC Gated ADC (Hoshin C009-H). It integrates the acquired signal within the injected gate signal. Unfortunately the minimum gate signal width is 1 μs, while the ICT signal width is 150 ns. Therefore, the integration for the short signals is not optimized. Moreover, the rest of the gate width, which is 850 ns, add an additional noise into the beam intensity measurement and decrease the measurement resolution. In order to improve the resolution, the RedPitaya STEMlab 125-14 [1] (see Fig. 2) FPGA board based digitizer was introduced into the beam intensity monitor DAQ system. The board is equipped with System on Chip (SoC), two channel DC-coupled 14 bit ADC, two channel DC-coupled 14 bit DAC with 125 MSa/s sampling rate and additional 12 bit ADC with 100 kSa/s sampling rate. The internal oscillator supplies the clock for the periphery chips and SoC. The board utilizes Linux Debian OS.

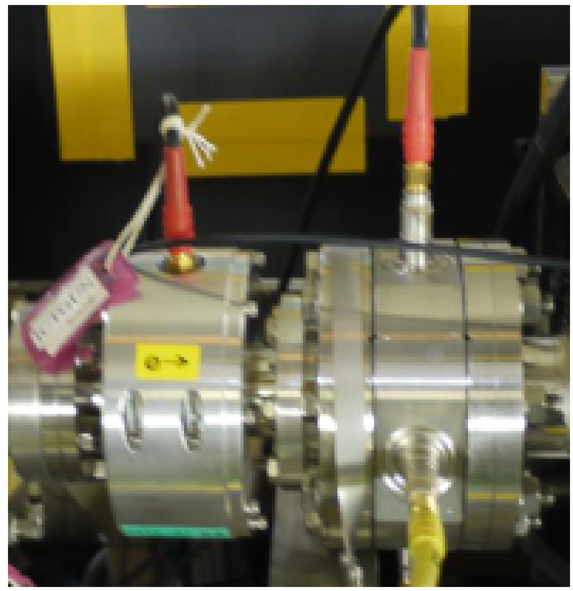

Figure 1: KEK ATF RF-Gun ICT photo.

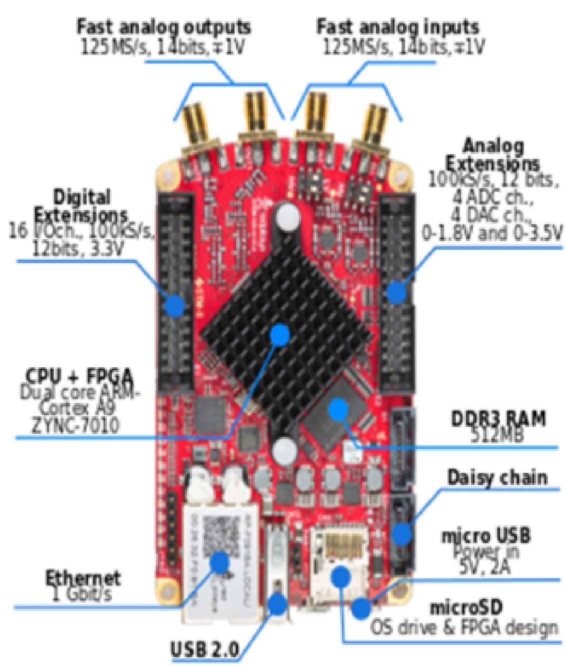

Figure 2: RedPitaya STEMlab 125-14 FPGA board overview.

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As an example, the KEK ATF RF-Gun ICT signal processing details will be explained in this paper. The rest of ICTs signals has the identical signal processing routine.

INTEGRATING CURRENT TRANSFORMER SIGNAL PROCESSING

CAMAC DAQ system was based on the Gated ADC and its crate controller (see Fig. 3). The ICT signal is transmitted from the tunnel to the DAQ station via RF cable. Then, the signal polarity is flipped using RF transformer [2], because CAMAC Gated ADC is unipolar. It can integrate only the negative polarity signals. The inverted ICT signal is integrated by the ADC within the gate signal width. Then the digital data is sent from the ADC to the CAMAC crate controller, while the controller publish the beam intensity information to the EPICS [3] PV, which is displayed at the control PC Graphical User Interface (GUI) at the control room. The signal polarity change is required only for the KEK ATF RF-Gun ICT.

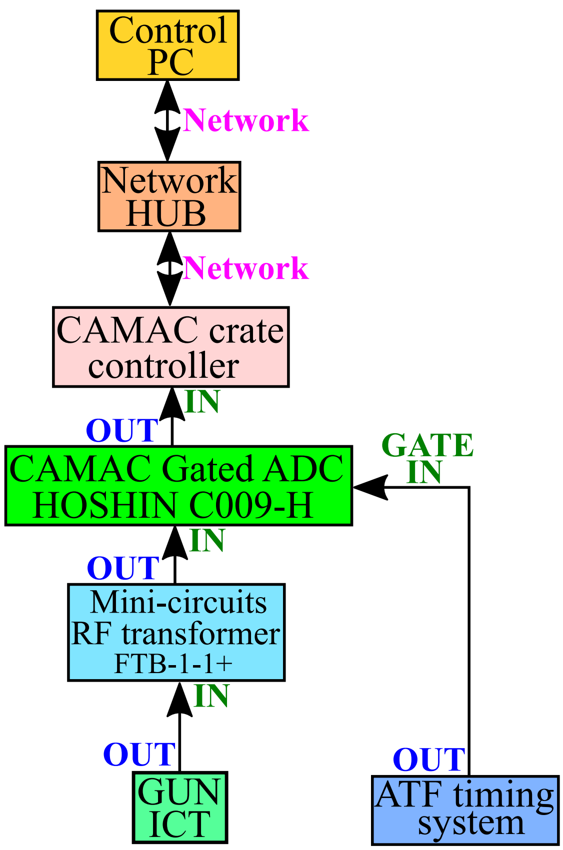

Figure 3: KEK ATF RF-Gun ICT signal processing diagram based on CAMAC Gated ADC.

The RedPitaya STEMlab 125-14 FPGA board based DAQ system includes the RF-ampliifer, Low-Pass Filter, impedance matching pod and the FPGA board itself (see Fig. 4). The signal amplitude is attenuated during the propagation, therefore its amplification is necessary to digitize ICT signal waveform by RedPitaya STEMlab 125-14 FPGA board. The amplified signal is filtered by Low-Pass Filter of 100 MHz bandwidth [4] to reject the induced noise caused by the amplification.

Then, the signal is fed to the FPGA board ADC input through the impedance matching pod [5] to match the board ADC High-Z input impedance with the RF-amplifier and Low-Pass Filter 50 Ohm output impedance.

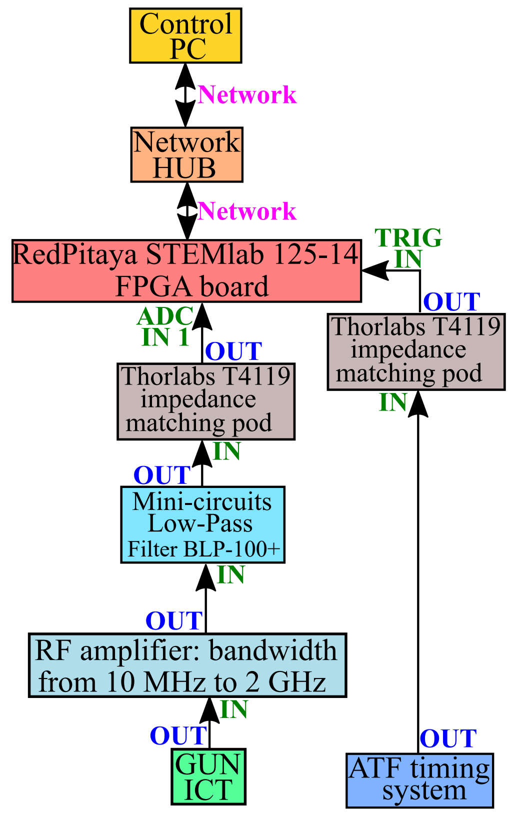

Figure 4: KEK ATF RF-Gun ICT signal processing diagram based on RedPitaya STEMlab 125-14 FPGA board.

The KEK ATF RF-Gun ICT signal waveform is shown on the Fig. 5.

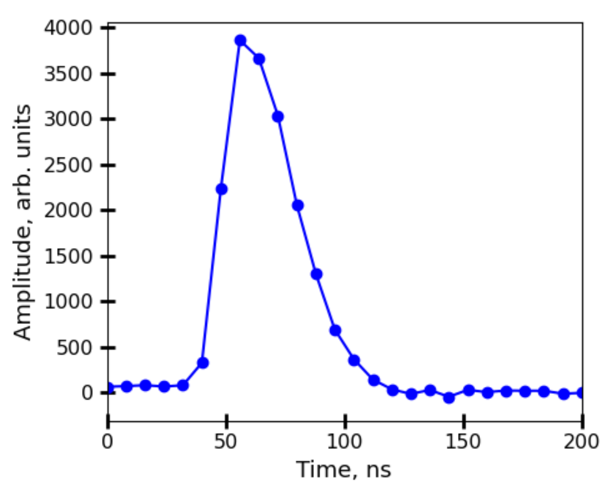

Figure 5: KEK ATF RF-Gun ICT signal waveform.

The waveform peak is integrated over 15 points. Then, the background is measured by integrating the first 3 data points of the waveform every machine cycle and subtracted from the peak integrated value. It is a dynamic background subtraction, which is the digitizer based DAQ system advantage over the CAMAC Gated ADC based DAQ system. Finally, the beam intensity is calculated at the SoC CPU using the calibration curve. The calibration curve (see Fig. 6) was measured by changing the RF-Gun laser power and acquiring the beam intensity value, as well as integrating RF-Gun ICT signal waveform peak.

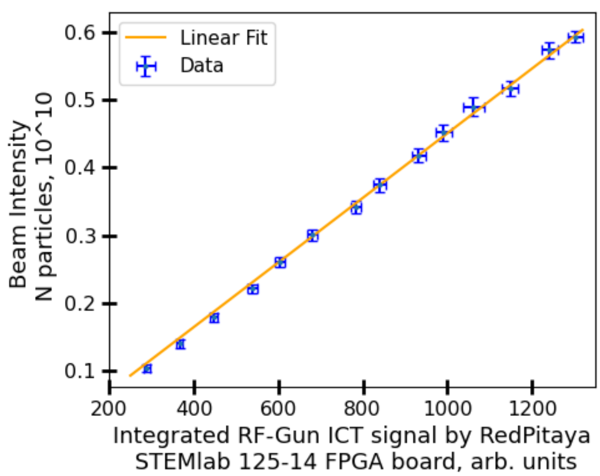

Figure 6: KEK ATF RF-Gun ICT callibration curve: (blue dots with error bars) is the beam intensity vs integrated KEK ATF RF-Gun ICT signal waveform peak, (orange solid line) is the linear fit: amplitude $-0.027324 \cdot 10^{10}$ particles and slope $0.000478 \cdot 10^{10}$ particles/arb. units.

The calculation routine is implemented into EPICS [3] using "acalc" record [6]. Moreover, the digitizer software and local EPICS IOC starts up on the FPGA board boot using the "shell" script and "crontab" utility.

EXPERIMENTAL RESULTS

The experiment was performed to compare the CAMAC Gated ADC based beam intensity measurement resolution with the FPGA board one. The beam intensity was measured every machine cycle of 3.125 Hz over 10 minutes by both systems. The results are depicted at the Fig. 7 and 8.

As can be seen from the experimental results, the beam intensity measured with CAMAC Gated ADC jitters between $0.48{\cdot}10^{10}$ electrons and $0.40{\cdot}10^{10}$ electrons, while the beam intensity measured with RedPitaya STEMlab 125-14 FPGA board based digitizer jitters between $0.44{\cdot}10^{10}$ electrons and $0.42{\cdot}10^{10}$ electrons.

The experimental data does not show the beam intensity drift or fluctuation. It demonstrates only the jitter, which has a Gaussian form (see Fig. 8).

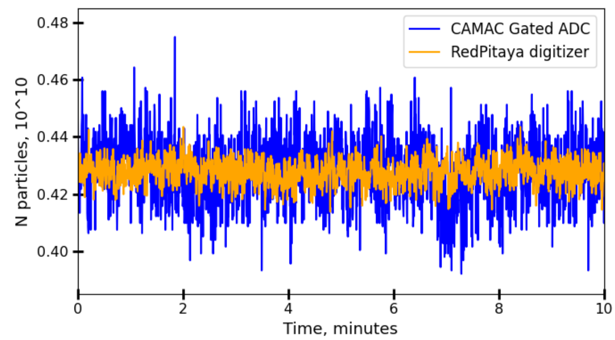

Figure 7: KEK ATF RF-Gun ICT DAQ systems beam intensity measurement results: (blue line) is the beam intensity measured by CAMAC Gated ADC vs time, (orange line) is the beam intensity measured by RedPitaya STEMlab 125-14 FPGA board based digitizer vs time.

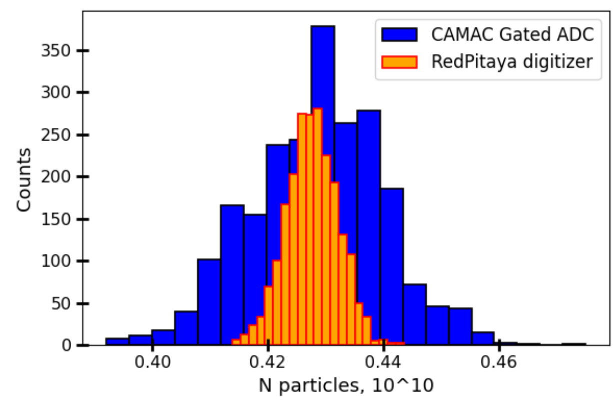

Figure 8: KEK ATF RF-Gun ICT DAQ systems beam intensity measurement results: (blue histogram) is the beam intensity measured by CAMAC Gated ADC, (orange histogram) is the beam intensity measured by RedPitaya STEMlab 125-14 FPGA board based digitizer.

CONCLUSION

RedPitaya STEMlab 125-14 FPGA board based digitizer acquires and integrates the ICT entire waveform peak. The beam intensity jitter was improved from 3.5 % (RMS) to 1.6 % (RMS) by eliminating the fake jitter caused by unoptimized gate signal width. Also, the background dynamic subtraction improved the beam intensity resolution. As a result, this upgrade demonstrated two times better beam intensity and its transmission measurement resolution than the previous system, and contributes to the improvement of ATF beam tuning.

ACKNOWLEDGEMENTS

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