Improvement of Bunch Arrival Time Monitor readout electronics by upgrade to uTCA

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Abstract

This poster presets the aspects of upgrade the Bunch Arrival time Monitor (BAM) readout electronics to the new version made in the uTCA form factor. Previous version was made in the VME standard - as the rest of electronics in FLASH. Development of the electronics for X-FEL (and also FLASH, as a X-FEL test facility), brought the uTCA as officially chosen standard for electronic devices. This technology makes new possibilities in comparison with the VME. Creating new design of electronic system is good occasion to improve it's performance. uTCA backplane has much higher throughput than VME, and also point-to-point links avoids the case when one board acquires the multi-drop, affecting affecting the other boards communication performance.

Improved data transfer on the backplane and faster CPU boards removes the limitation of maximum amount of data which could be processed between accelerator pulses, which has been reached in the old VME system. This opens the way for using high-performance fast ADCs with sampling frequency ¿ 200MHz. Usage of fast ADCs will increase the performance, solve several issues, and in several places will simplify the system.

Beam feedbacks

The LLRF systems closes the feedback loop on the RF field amplitude and phase stability, assuming that if the RF field is more stable - than the beam also. This is not allays true, as shown in the figure 1, the beam fluctuations increases with the higher gain values due to the amplification of noises.

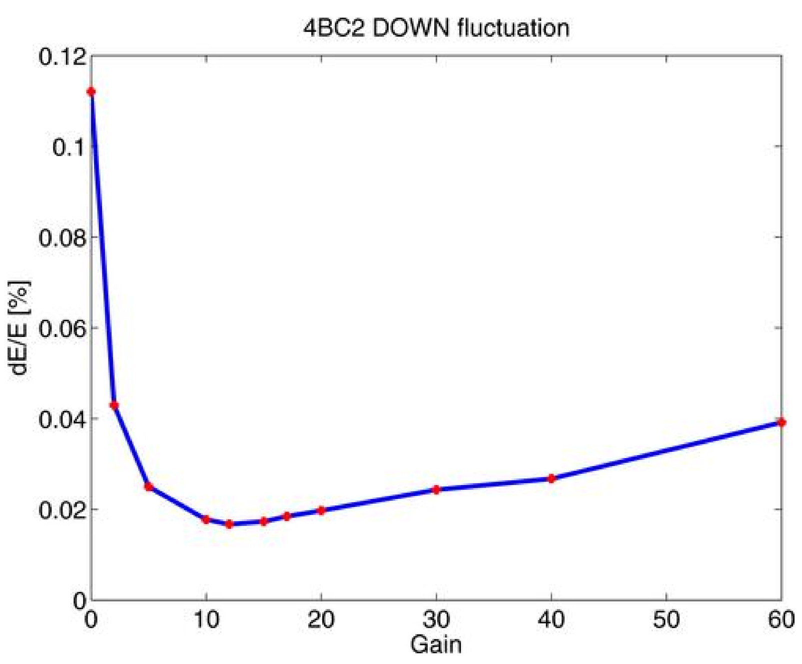


Figure 1: Beam stability measurement in FLASH

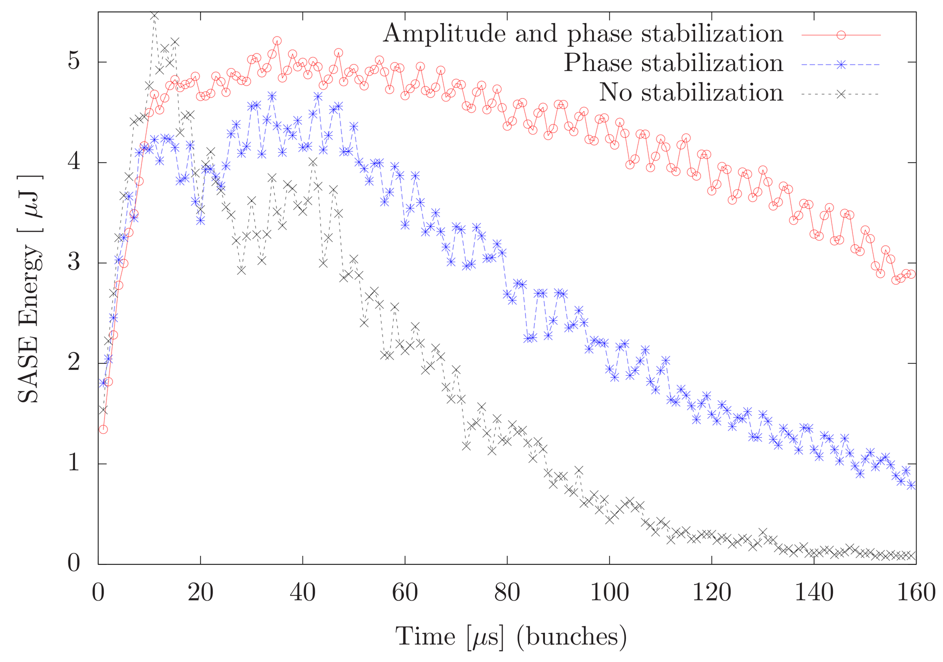


Figure 2: Average SASE energy over the bunch train

Beam feedback system improves the LLRF control by providing information about the actual beam parameters in the real time. With this information, the feedback loop can be closed to maximize the beam stability instead the RF field itself. The improvement of generated SASE radiation is shown in the figure 2.

Bunch Arrival time Monitor readout

Due to estimate the energy of the electron bunch, signal from the BAM detector is used to modulate the laser pulses (fig. 3) by electro-optical modulator (EOM). These laser pulses are generated with the frequency of 216 MHz. During regular operation in FLASH, bunches are generated with frequency of 1 MHz, which means that every 216-th laser pulse will be modulated, and these modulated pulsed are in the center of out interest.

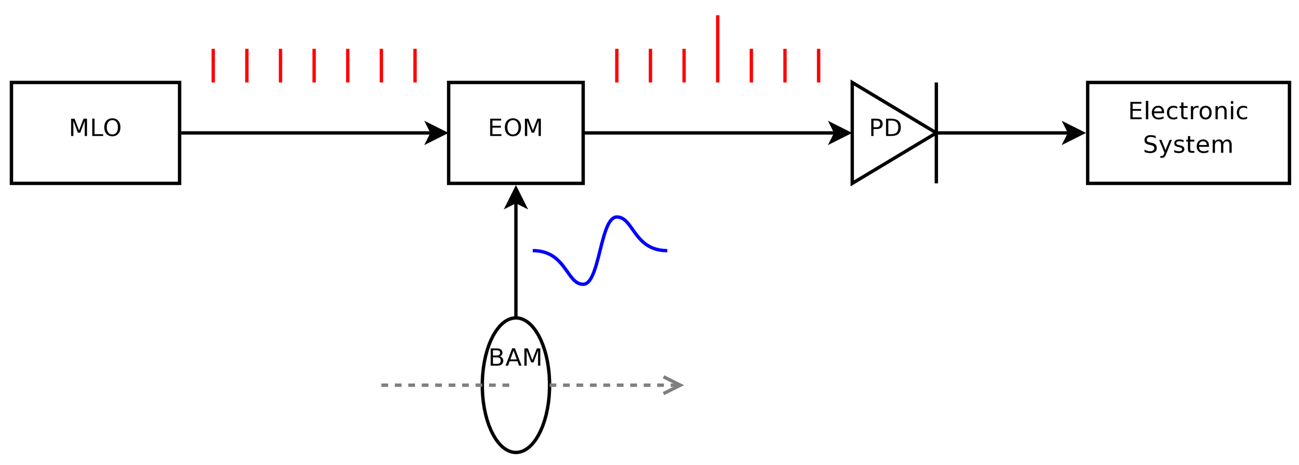


Figure 3: The general concept of the laser pulses modulation

The height of modulated laser pulse is proportional to the arrival time. The way how the pulses are modulated by the arrival time of the electron bunch is shown in the figure 4.

The arrival time is used here as an estimate of the electron bunch energy. It is possible, because depending on the energy, electrons travel on different-length ways in the bunch compressor - electrons with higher energy travels using the shorter path, and will arrive earlier, and the electrons with the lower energy, will travel over longer way, which will result in later arrival.

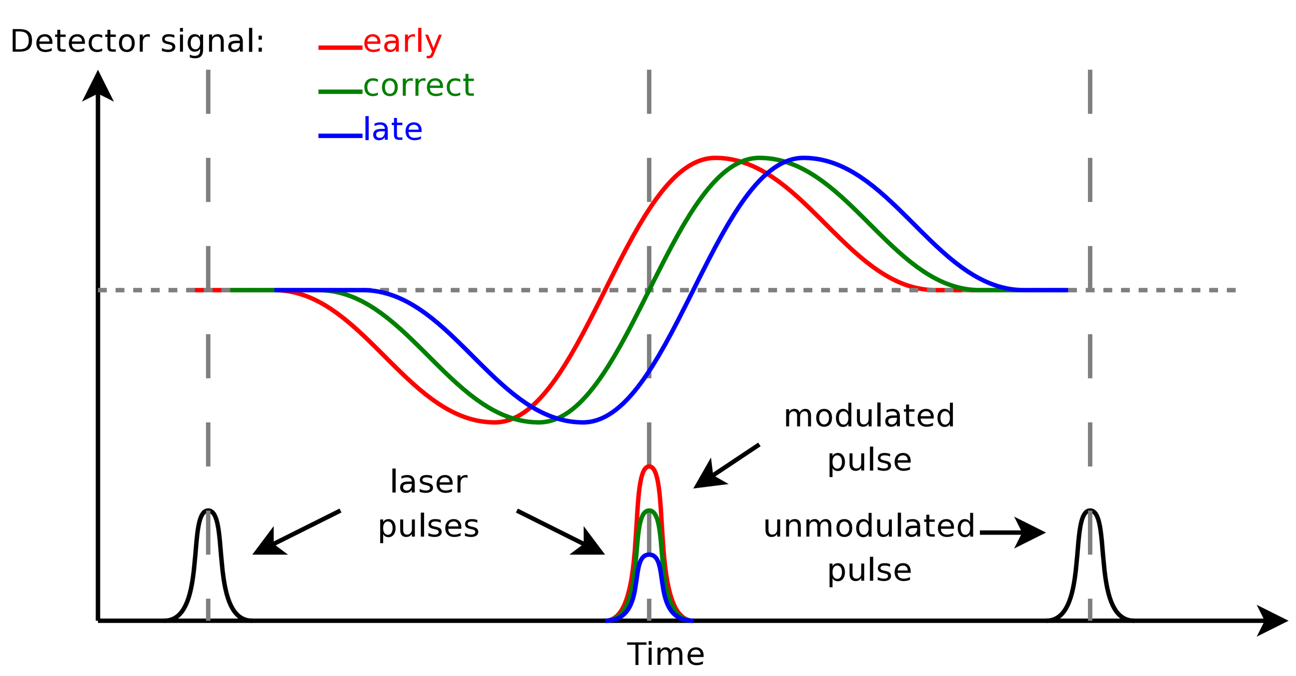
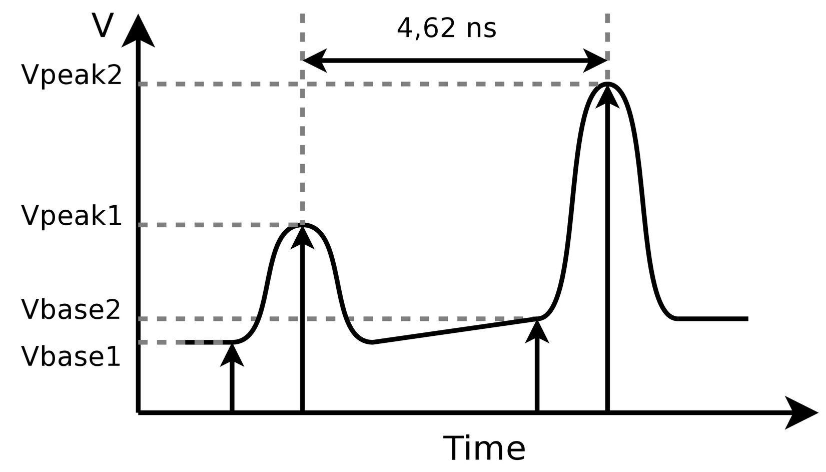


Figure 4: Modulation of the laser pulses by the signal from the BAM detector

More information about the BAM operation can be found in [3].

Amplitude correction

To regulate to minimize the beam fluctuations, proper correction of the RF field amplitude has to be estimated, and applied to the LLRF system. The absolute height of the modulated pulse is not accurate enough, because of the drifts of the signal. Better results gives the relative height of the pulse. To have the reasonable correction value, relative height of the modulated pulse must me compared with unmodulated one. The the method of the amplitude correction estimation is show in the figure 5 and equation 1.



$$A_{corr} = \frac{V_{peak2} - V_{base2}}{V_{peak1} - V_{base1}} \qquad (1)$$

Figure 5: Laser pulses sampling for relative height estimation

This method of amplitude correction gives the proper amplitude correction, proportional to the arrival time of the electron bunch.

The old VME system

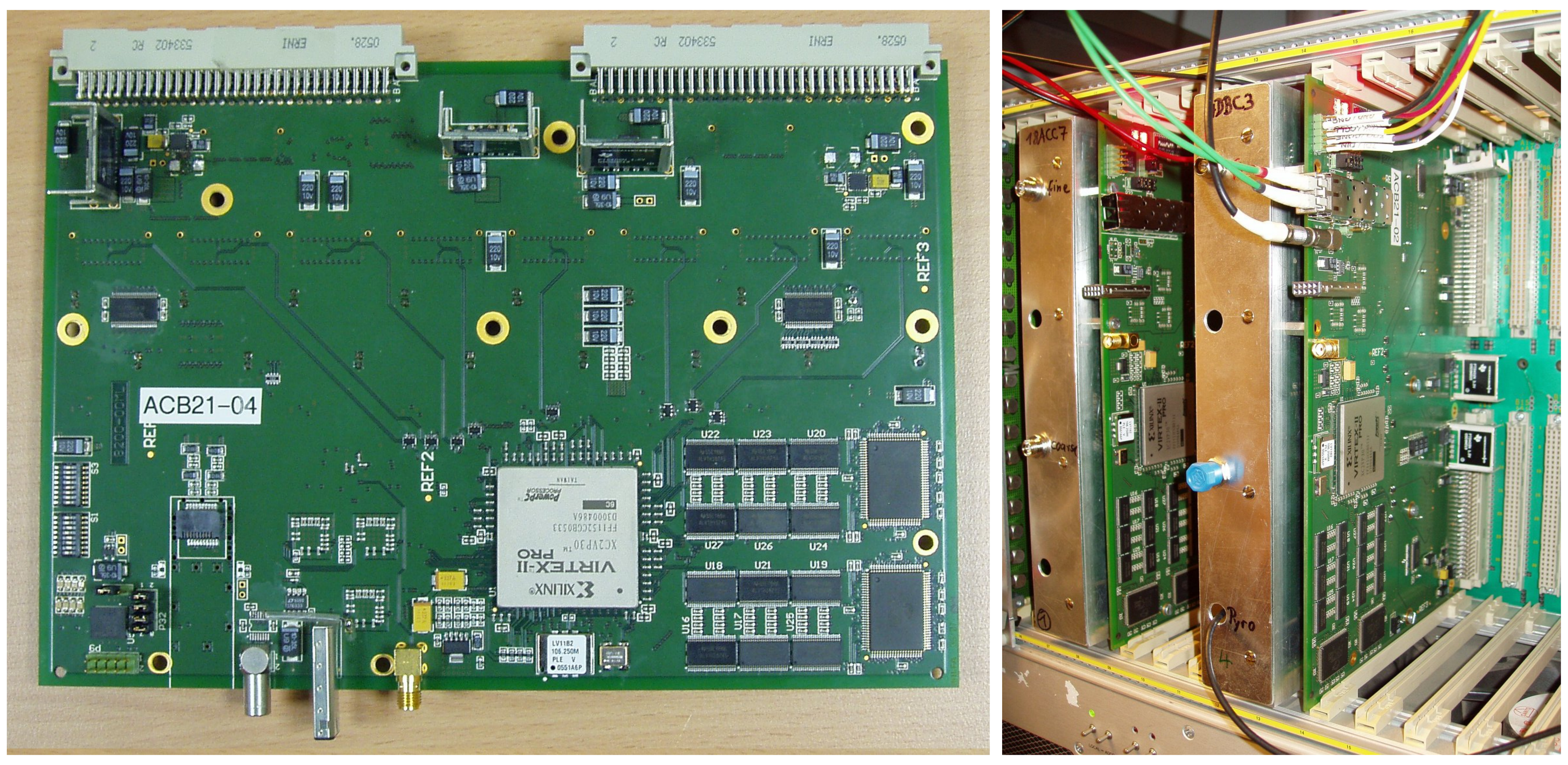


Figure 6: ACB 2.1 board

The VME based system was able to sample laser pulses with maximal frequency of 125MHz, so the only available scheme for sampling was sampling with 108 MHz (fig. 1) which means of every second pulse. The disadvantage of this method was that incorrect synchronization caused sampling wrong samples, that the modulated samples has not been seen. Another problem is that 2 ADCs are needed, one ADC for sampling the base line, and the second one for sampling the peak. This means that signal has to be splitted into 2 lines which goes to 2 ADCs. This kind of splitting may decrease the signal quality. To achieve precise sampling of narrow peaks and baselines, the clocks for ADCs has been adjusted using clock distribution devices with fine phase delay control.

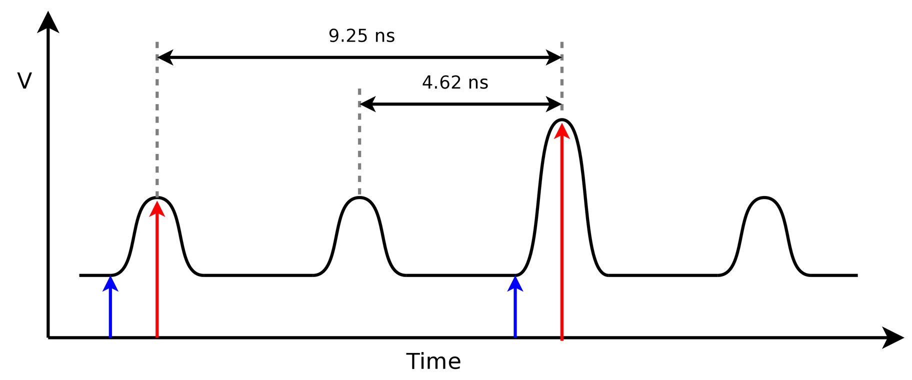


Figure 7: Sampling with 108 MHz and 2 ADCs

Improvement in the new uTCA system

New design based on uTCA opens the door for using faster ADCs, so new sampling schemes may be used. The the easiest way to improve the system, is to increase the sampling frequency to the 216 MHz, and then every laser pulse will be sampled (fig. 1), but still 2 ADCs are needed.

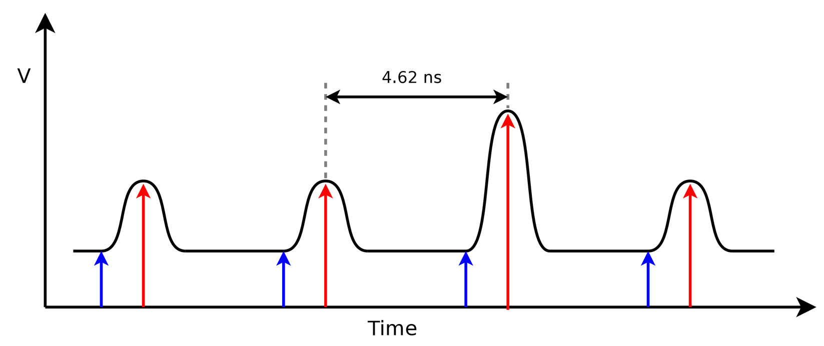


Figure 8: Sampling with 216 MHz and 2 ADCs

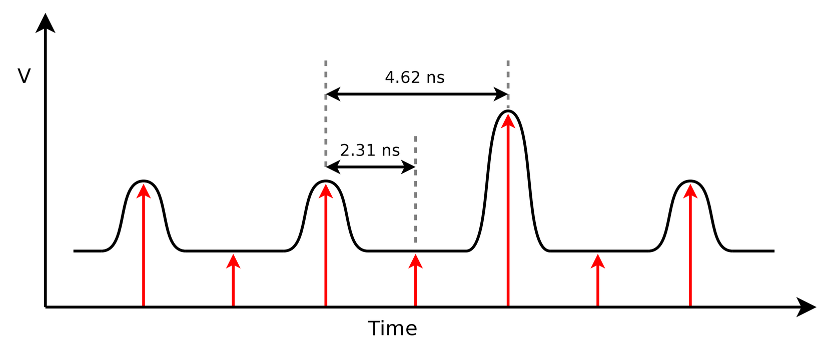


Figure 9: Sampling with 432 MHz and 1 ADC

To solve the problem of having 2 ADCs, again the sampling frequency may be doubled to the 432 MHz, and then both, the peak and the base line may be sampled with one ADC.

The new system will be made as the double height AMC board, compatible with DESY standards. The board will be a carrier for 2 FMC slots, on which the mezzanine boards with ADCs will be plugged. This modular architecture allows to test different types of ADCs. More details about the carrier board may be found in [1], details about fast ADCs usage can be found in [2]

References

1. Stefan Korolczuk, uTCA fast ADC board for Bunch Arrival Time Monitor signals processing, LLRF 2011
2. Samer Bou Habib, Eight-channel Fast ADC card for Direct Sampling of GHz Signals, LLRF 2011
3. F. Löhl, et. al, Electron bunch timing with femtosecond precision in a superconducting free-electron laser, Physical Review Letters 2010.