EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH
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CERN − AB DIVISION

AB−Note−2004−059 BDI

Using a Libera[1] signal processor for acquiring position data from the PS orbit pick−ups

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Abstract

To assess the quality of the measurements that can be expected from a new acquisition system for the particle trajectories in the PS accelerator, some measurements were made using a Libera[1] digital signal processor recently. This note presents an analysis of the results.

Geneva, Switzerland
July 28, 2004

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1 Introduction

On July 8, 2004, a prototype Libera[2] pick−up signal processor was used to acquire signals from a PS pick−up, in order to assess its suitability as a component of the projected new trajectory acquisition system. The Libera consists of four 125 MSPS 12-bit ADCs, connected to a Xilinx Virtex II Pro FPGA and a 256MB SDRAM. The device was connected to PU63. The four channels digitised the Sum, X and Y signals, plus a locally available copy of the revolution frequency.

The prototype used for this test was subject to some limitations: It could only acquire 32768 samples per channel, and it could not be externally triggered. This implies that it could only acquire about 120 turns worth of data at a more or less random instant of the machine cycle.

Despite these problems, we succeeded in obtaining enough data to assess the quality of the measurements.

2 Characteristics of the signal

The signal from a PS pick-up is bandwidth limited from 200 kHz to about 30 MHz. The lack of DC response implies that the base line of the signal, i.e., the level displayed in between bunches of particles, will drift to keep the long term average DC value at zero. The PU pre−amplifiers have a lot of gain near the low frequency end of the bandwidth. Therefore, the signal spectrum contains quite a lot of low frequency noise. The treatment called ’base line restoration’ (BLR) mitigates the deleterious effects of these issues.

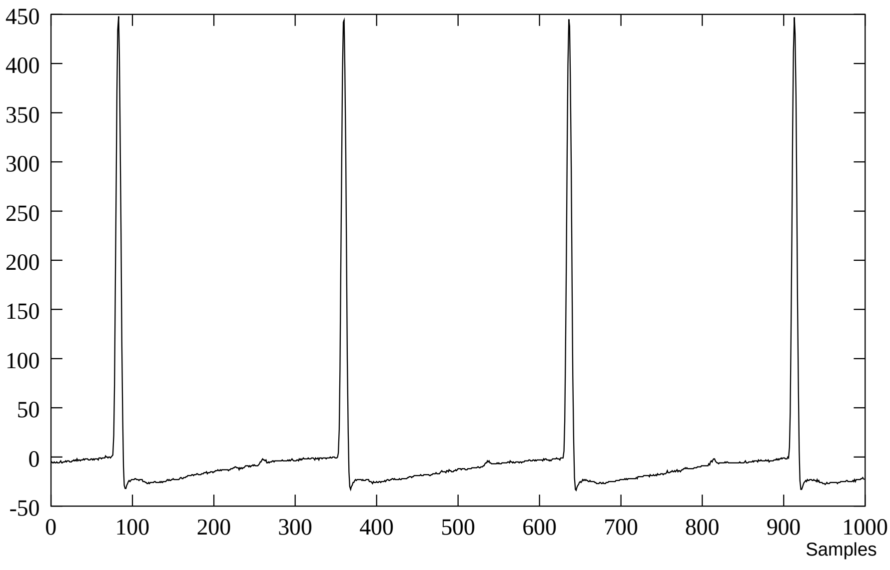

Fig 1: Raw (sum) data

The plot above shows the first 1000 samples of the sum signal as acquired by the Libera (Fig 1).

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3 Integration and base line restitution

For the trajectory system, the interesting parameter is the position of the centre of charge of each bunch. In order to obtain this value, the raw samples are integrated over the length of a bunch. The base line is sampled just before each bunch.

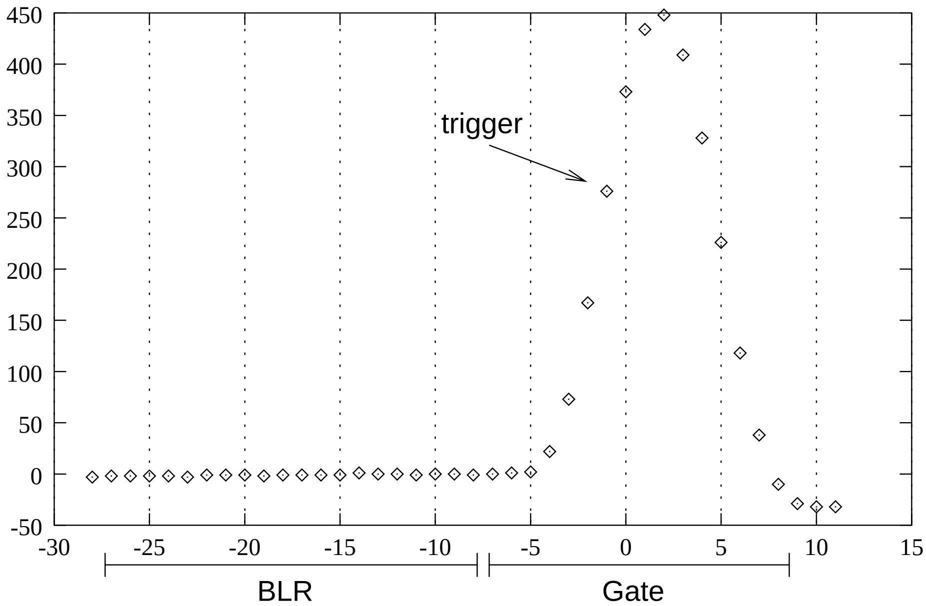

Fig 2: Gate and BLR intervals are defined with respect to the trigger event

The algorithm reads the sum data and detects a bunch by setting a trigger level. The gate and BLR intervals are defined as offsets and lengths with respect to the sample following the trigger event. (Fig 2)

The base line is calculated by applying a simple first order IIR low-pass:

$$b_{n+1} = 0.9b_n + 0.1y_n \qquad (1)$$

where b_n is the current output value of the filter, and y_n is the new sample. This filter has a time constant of about 9.5 samples. It receives only the samples that fall inside the base line intervals.

The integral is the simple mean of the samples inside the gate interval, minus the most recent value of the base line.

$$S=\frac{1}{m}\sum_{n=1}^{m} y_n - b \qquad (2)$$

4 Analysis of acquired data

The data set that will be analysed comes from an EASTC cycle. The beam is a single bunch of about $1.5 \cdot 10^{10}$ ppb. Fig 3 shows the first 400 samples from a total of 32768, taken from the Σ signal (large positive peaks) and the X signal (small negative peaks).

It spans 119 revolutions. From the data, we can obtain the revolution frequency F_{rev} = 455.5 kHz, corresponding to a kinetic energy of 2.2 GeV, which places it a few tens of ms after the start of acceleration[1].

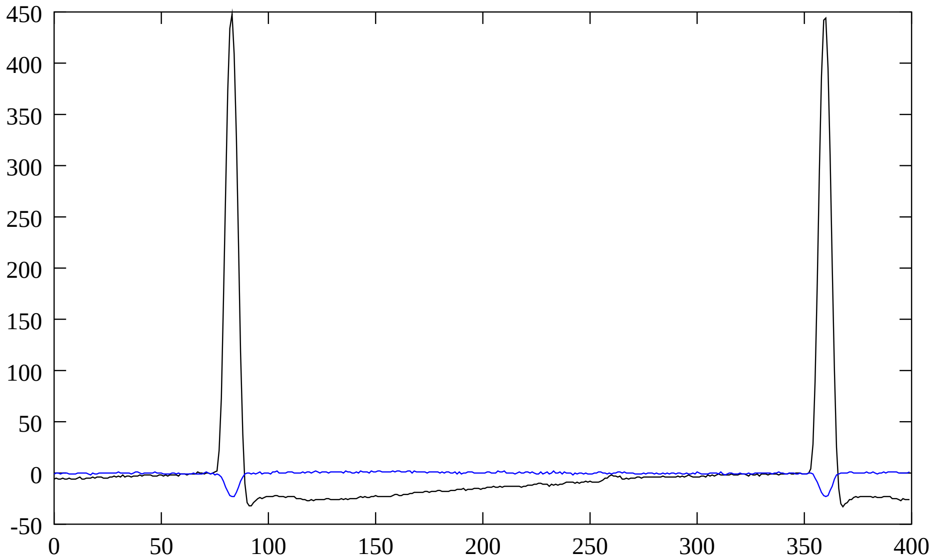

Fig 3: Σ and X signal from EASTC

It is obvious that the ADC is not very well filled. The ADC has a full scale range of −2048 to +2047, while the Σ data peaks near 450. The signal is about 12dB below full scale. Even so, the pre−amplifier noise, rather than the ADC noise, is the dominating contribution, so the values derived below should be representative, even had the ADCs been better filled.

For both signals, the 119 integrals were determined. The trigger instant (T) is always derived from the Σ signal. The integration parameters were set as follows:

- Trigger level 200 counts (The fastest slope.)
- BLR for 20 samples starting from T−27.
- Gate for 16 samples starting from T−7.

This yielded the following statistics:

	Mean	σ	
Σ	*182.0146*	*0.6390*	*(counts)*
X	*−9.5557*	*0.4823*	*(counts)*
X/Σ	*−0.0525*	*0.0027*	*(counts)*
S_xX/Σ	*−2.1000*	*0.1069*	*(mm)*

So the measured mean horizontal position over 119 turns is −2.1 mm, with a standard error of 0.1 mm (S_x = 40 mm is the position sensitivity of the PU). The validity of the measurement depends on a few assumptions: The beam passes through the same horizontal position for all 119 turns, and the measurement errors on Σ and X are normally distributed and independent. The standard deviation of the position measurements agrees with the value expected for the quotient of two independent normally distributed sets of measurements:

$$\sigma_{X/\Sigma} = \frac{\overline{X}}{\overline{\Sigma}} \sqrt{\frac{\sigma_X^2}{\overline{X}^2} + \frac{\sigma_\Sigma^2}{\overline{\Sigma}^2}} \qquad (3)$$

The scatter plot in (Fig 4) shows the X values against the associated Σ values, and lends credibility to the independency between them. The correlation coefficient is 0.09. This is within one standard deviation from zero for a distribution of this size.

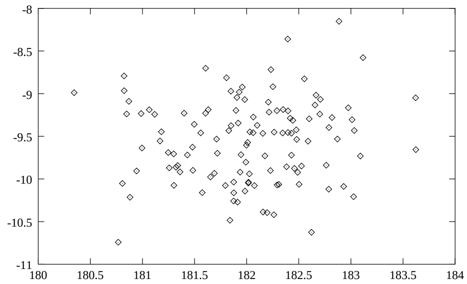

Fig 4: Scatter plot X vs Σ integrals

The two plots below show histograms of the Σ (Fig 5) and X (Fig 6) values respectively, showing the distribution of measured values.

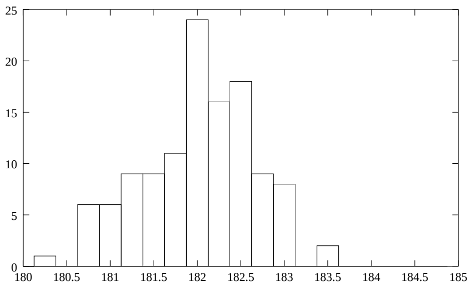

Fig 5: Histogram of Σ integral values

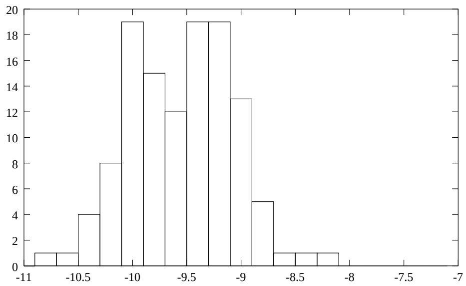

Fig 6: Histogram of X integral values

5 Conclusion

Despite the difficulties encountered with the Libera trigger, some useful data could be obtained, albeit, unfortunately, only on EASTC type beams. Simple analysis shows that the target position resolution of 0.1 mm for a single pass trajectory measurement is possible. The resolution appears to be limited by noise from the pre−amplifiers, and not by that of the ADCs. The sample rate of 125 MSPS appears to be sufficient.

References

[1] H.H. Umstatter, Tables of dynamic parameters of the CPS, CERN−MPS−Int−SR−68−7