



Instrumentation
Technologies

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Libera Bunch-by-Bunch

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Libera **WORKSHOP**
2008

14 October 2008

Libera Bunch-by-Bunch Processing Unit

Libera Bunch-by-Bunch is used for digital processing of the signal that was pre-processed with the Libera Bunch-by-Bunch Front End unit.

It enables the user to close the bunch-by-bunch feedback loop or to perform bunch cleaning.



Libera Bunch-by-Bunch Processing Unit

Features of the Libera Bunch-by-Bunch 1.85:

- **FIR filter**
- **Single bunch FIR filtering**
- **Input and output delay**
- **Phase shift**
- **DDR2 RAM input selection** (ADC or processed data)
- **Trigger type** (standard or initiated at the start of data processing cycle)
- **Gain setting** (general gain for all bunches and gain per bunch)
- **NCO generator for bunch purification**
- **DAC operating mode** (off – sends constant value to the output or on – sends processed samples to the output)

Libera Bunch-by-Bunch Setup

- **Libera Bunch-by-Bunch with SW version 1.85**
- **Graphical User Interface – GUI**
- **Machine clock – 500 MHz**
- **Input signal – arbitrary sine signal**
- **Output signal to oscilloscope**



FIR Filtering

The number of processing chains in Libera Bunch-by-Bunch is adequate to the synchrotron harmonic number.

Basic digital processing is 16-tap FIR filtering module. 16 FIR filter coefficients have to be set for each processing chain.

Same coefficients can be used for all processing chains or different coefficients can be set for each chain.

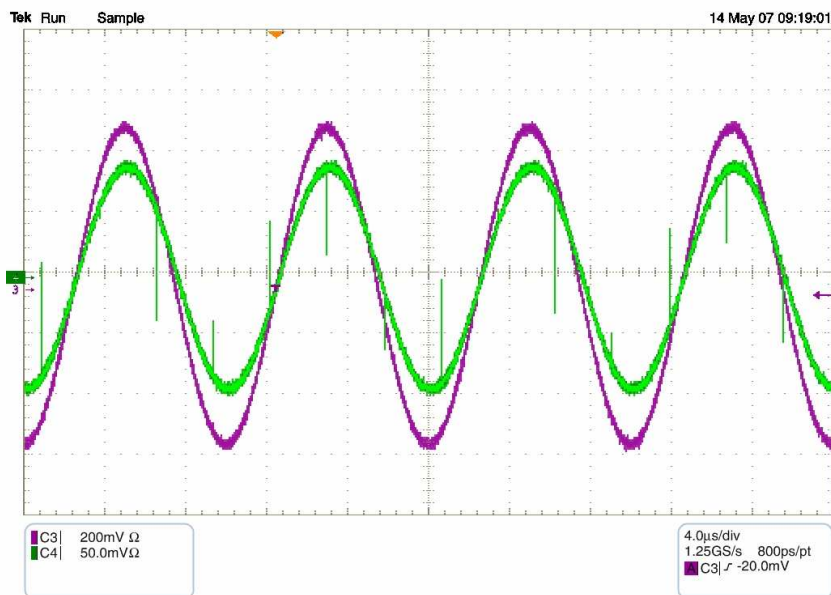
FIR Filtering

- **16-tap FIR filter**
- **Same FIR filter coefficients for all processing chains**
- **Loading of coefficients**
- **“Straight-through” coefficients**
- **FIR filter coefficients all 0**
- **Horizontal FIR filter for CLS**



Single Bunch FIR Filtering

Single bunch FIR filtering is done identically as the general FIR filtering. The only difference is that coefficients are applied to a single bunch in a processing chain. Single FIR filter coefficients can be set for one bunch in each processing chain.



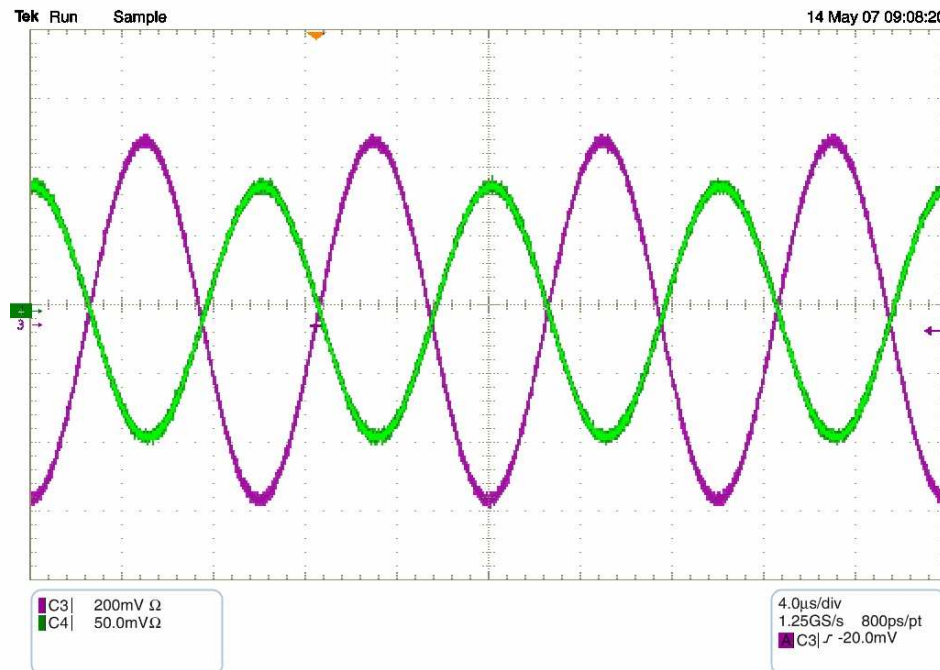
EXAMPLE: Main FIR filter coefficients are initialized with demo coefficient values. Single filter settings in chains 2, 3 and 4 were disabled; only coefficients for the first bunch in processing chain 1 were set to zero value.

Single Bunch FIR Filtering

- **One bunch in one processing chain filtered with independent coefficients**
- **Loading coefficients with GUI**

Phase Setting

An important feature of the signal applied at the kicker is that its phase must be $\pi/2$ shifted compared to the source signal: this value of phase difference reduces the oscillations.



EXAMPLE: Output signal was phase shifted for 3.14 *rad*.

Phase Setting

- **Adjustable phase of the output signal**
- **Range between $-\pi$ and π**
- **Setting phase with GUI**

Delay Setting

Calculated correction should be applied at the kicker at the exact moment when the bunch (which is the source for the processed signal) is bypassing. To achieve this, delay tuning is required.

There is the possibility to set the input and output delay of the signal processed in the FPGA.

The delay can be set between 0 ns and revolution period in steps of $1/f_{RF}$ (~2 ns).

Delay Setting

- **Adjustable input and output delay**
- **Delay can be set between 0 ns and revolution period in steps $1/f_{RF}$ (~ 2 ns)**
- **Setting delay with GUI**

DAC Operating Mode

- **Digital-to-analog converter (DAC) turned 'off' → sends constant value to the output**
- **DAC turned 'on' → sends processed samples to the analog output**
- **Setting DAC operating mode with GUI**

General Gain Applicable to all Bunches

- **Gain setting performed by bit scaling**
- **Right or left shift up to 8 bits possible → resulting in gain from 2^{-8} to 2^8**
- **Setting gain with GUI**

Numerically Controlled Oscillator (NCO)

- **NCO implemented for bunch cleaning purposes**
- **NCO generates set of frequencies in the proximity of the betatron oscillation and thus drives the particles to unstable state**
- **For each bunch the NCO signal or processed signal can be propagated to the DAC**

Numerically Controlled Oscillator (NCO)

Parameters to be set:

- NCO bottom frequency (the lowest frequency of the NCO)
- NCO ramp maximum (delta frequency of the NCO sweep)
- NCO ramp step (time in which the NCO sweeps through frequencies, starting from the NCO bottom frequency and ending at the frequency equal to the sum of NCO bottom frequency and delta NCO frequency)
- NCO ramp repeat (number of sweep periods)
- NCO output mode (sine or rectangular signal or NCO inactive – no output)

Gain per Bunch and NCO Mask per Bunch

- Individual gain setting for each bunch
- Range: -1 to 1
- NCO mask per bunch: user can select for each bunch whether NCO generated signal or processed signal is sent to the DAC
- NCO mask per bunch setting with GUI

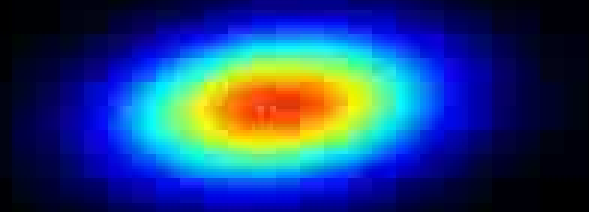
Data Acquisition with GUI

Data acquisition parameters

- number of samples
- data offset
- step
- trigger options

Plot parameters

- type of data plot
- data scaling



Courtesy of
Guenter Rehm