

Bunch-by-Bunch Processing on MicroTCA at Diamond

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Scope of this talk

I will talk about signal processing for Multi-Bunch Feedback

- ▶ Focus on digital chain of bunch-by-bunch processing
- ▶ Input and output at up to 500 MHz, baseband, taken as given
- ▶ Assume pickups, front-ends, amplifiers, transducers, etc already given

Focus will be on applications and capabilities.

Applications

Applications of MBF (Multi-Bunch Feedback) system

- ▶ Beam stabilisation
- ▶ Tune measurement
- ▶ Diagnostics and Machine Physics experiments
- ▶ Post-Mortem Analysis

History of MBF at DLS

The immediate precursor to Multi-Bunch Feedback at Diamond Light Source is:

- ▶ ESRF, Eric Plouviez et al., reported 2006, implemented on the Libera platform, written using Xilinx System Generator.

At Diamond the following evolution occurred:

- ▶ Converted from System Generator to System Verilog by Isa Uzun, and tune sweep and individual bunch control added, reported 2008.
- ▶ Substantial rework by myself and Isa, reported 2013, introduction of sequencer and bunch bank control.
- ▶ Converted to VHDL to avoid licensing problems, adopted by ALBA 2014.
- ▶ Rewritten and ported to MicroTCA COTS hardware, 2016 to present.

MBF on MicroTCA

The Libera platform is based on 15 year old hardware, and our FPGA is full. Using MicroTCA lets us use modern Commercial Off The Shelf hardware for data acquisition, signal processing, control.

FPGA carrier Vadatech AMC525 provides a Virtex-690 FPGA (with 3,600 DSP units), 2GB of fast RAM, 8 lane PCIe3 interconnect, support for 2 FMC cards

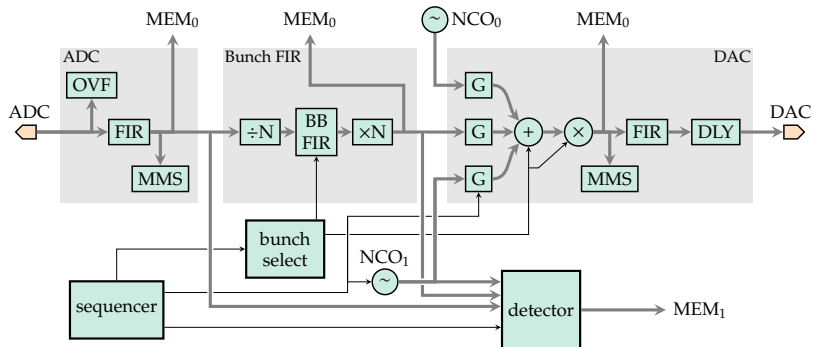
ADC/DAC FMC Dual 14-bit 500 MHz ADC and 16-bit DAC.

This platform gives us plenty of room and allows for high performance, in particular the $8\times$ PCIe3 readout of captured memory is valuable.

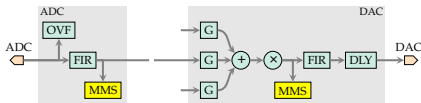
Capabilities of DLS MBF

- ▶ Bunch by bunch feedback with 16-tap FIR per bunch
- ▶ Up to four different FIRs selectable for different bunches
- ▶ ADC compensation and DAC pre-emphasis with FIR
- ▶ Dynamic view of bunch motion: min, max, mean, variance
- ▶ Programmable sequencer with swept NCO excitation and synchronous detector
- ▶ Capture and fast readout of up to 1 second (2 GB) of dual channel bunch by bunch data
- ▶ Longitudinal feedback supported via bunch by bunch downsampling on FIR and 90° channel phasing for IQ output

Signal Processing Chain

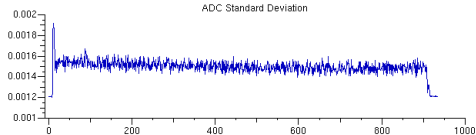
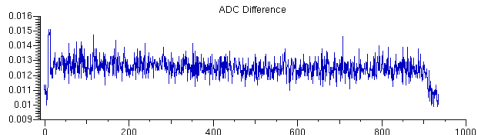
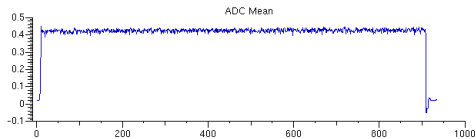
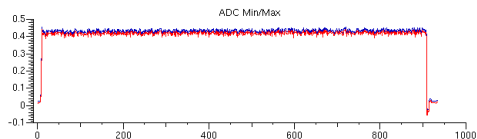


Min/Max/Sum (MMS)



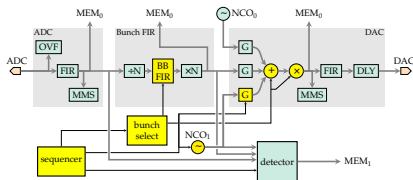
The MMS unit accumulates statistics for every bunch, which are then read out periodically (the default interval is 200 ms) and used to display the following overview information:

- ▶ Overall extent of beam motion (max – min)
- ▶ Standard deviation of beam motion
- ▶ Average beam position



Sample size: 100,000 turns, note standard deviation $\approx 10\%$ peak-to-peak

Sequencer and Bunch Select



The Bunch Select unit selects for each bunch:

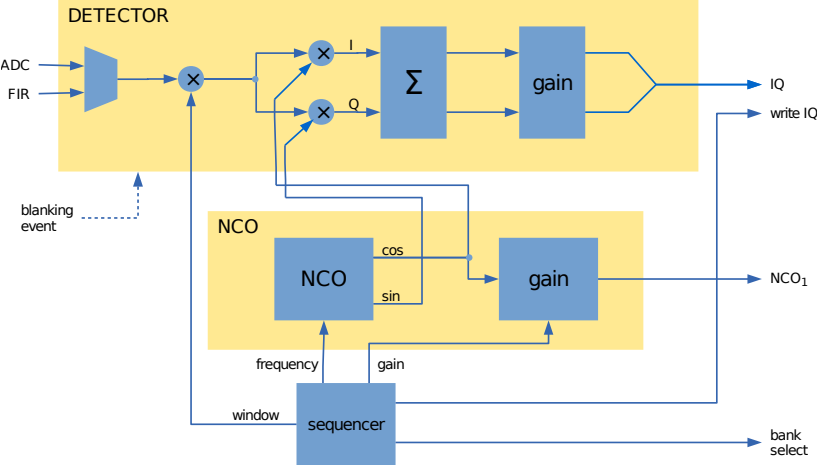
- ▶ Which of 4 FIRs to use on that bunch
- ▶ What combination of outputs for that bunch (NCOs and FIR)
- ▶ Overall bunch gain

The Sequencer provides up to 7 states to control:

- ▶ Sweep control (NCO frequency range, sweep rate, etc)
- ▶ Which of 4 bunch configurations to use

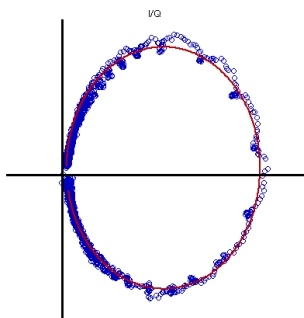
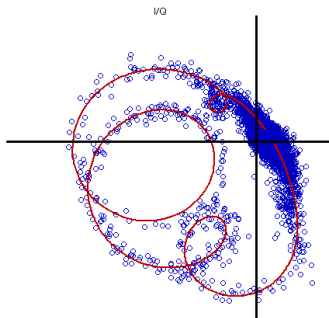
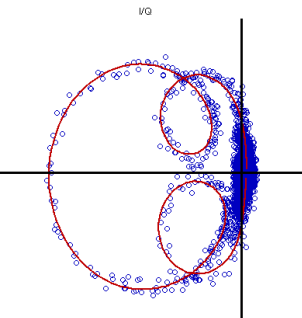
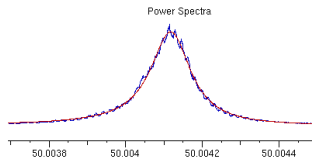
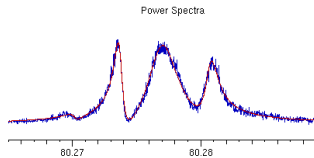
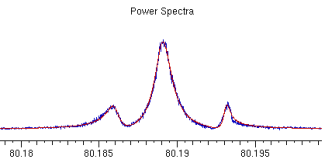
The Super Sequencer repeats a sequencer experiment for up to 1024 different frequency offsets; this is particularly useful for mode scan experiments.

Detector

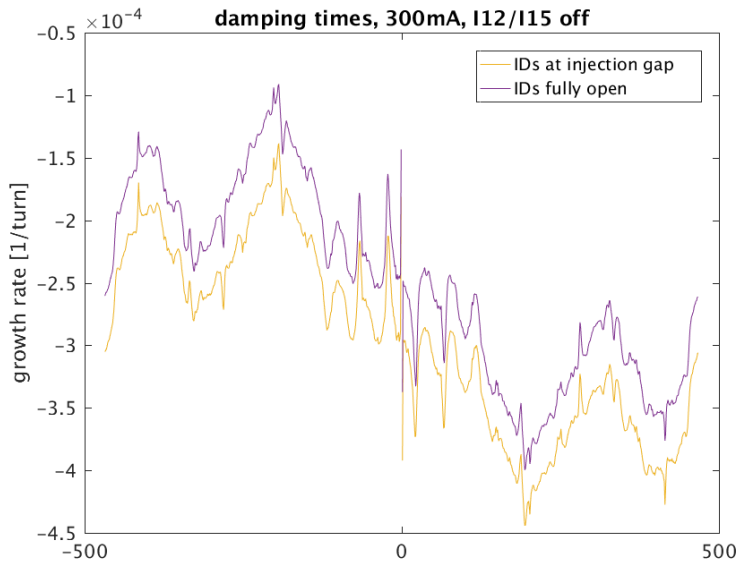


Tune Sweep

Examples of horizontal, vertical, and longitudinal tune sweeps with fitted models.



Longitudinal Mode Sweep Experiment



Sequencer Setup for Sweep

Sequencer						
	Sweep start	Sweep step	Sweep end	Magnitude	Bunch bank	
1	80.12200	0.0000244	80.22198	-48dB <input type="checkbox"/>	On <input type="checkbox"/>	Bank 1 <input type="checkbox"/>
	4096	0	100	Blanking <input type="checkbox"/>	Windowed <input type="checkbox"/>	Capture <input type="checkbox"/>
	Capture	Holdoff	Dwell time	Blanking	Data window	Data capture
Start:	1 0	Stop	Capture: 4096	Steady state:	Bank 0 <input type="checkbox"/>	
Super:	1 0		Duration: 0.767 s		Window	More States
			Offset: 0.00000			

Bunch Bank				
Bank	FIR select	DAC out status	DAC gain	
0	#0	FIR	1	Setup
1	#0	Sw+FIR	1	Setup
2	#0	Off	1	Setup
3	#0	Off	1	Setup

Future Developments

Three developments are planned for the immediate future

- ▶ Reimplement phase locked tune tracking on new system
- ▶ Use PLL tune tracking to compensate for tune drifting during experiments
- ▶ Provide functionality for playing precomputed data on to the beam. Possible applications include:
 - ▶ Feed forward correction of injection transients
 - ▶ Narrow band noise excitation for tune sweep