Introduction to the practical afternoon courses on DSP/FPGA designs

CAS 2007-DSP

Hermann Schmickler (CERN)
contents

• What do we want to achieve with the courses
• Boundary conditions
• Original options
• The physics case: PLL betatron tune tracking
• Translation into the lab setup
• Familiarization with DSP and FPGA design during 8 hours
• Every student does within 16 hours (7 afternoons) 8 hours DSP and 8 hours FPGA designs
• No chance to learn the syntax of any detailed design tool
• Very different starting points of individual students

• Choice:
  25 DSP workstations (PC plus evaluation board) + 25 FPGA workstations (PC plus evaluation board) + MATLAB/Simulink as high level graphical design environment
The DSP master:
Maria-Elena Angoletta (CERN)

Room A

The FPGA master
Javier Serrano (CERN)

Room B
What possibilities for the lab?

- Hands on: Real physical input/output
- Codec of DSP/FPGA cards
- Loudspeakers/headphones: no!
  No synthesizers, audio filters, speech recognition…
- Large synchrotrons (LEP, RHIC, HERA, LHC) have betatron tune within audio-bandwidth
- Decision to take as subject for the labs betatron tune diagnostics
The virtual accelerator (one plane only)
Measurement of Q (betatron tune)

- **Q** – the eigenfrequency of betatron oscillations in a circular machine
  - One of the key parameters of machine operation
- **Many measurement methods available:**
  - different beam excitations
  - different observations of resulting beam oscillation
  - different data treatment

Characteristic Frequency of the Magnet Lattice
Produced by the strength of the Quadrupole magnets
Principle of any Q-measurement

Beams

\[ G(\omega) \]

Excitation Source for Transverse beam Oscillations
- stripline kickers
- pulsed magnets

\[ BTF := \frac{H(\omega)}{G(\omega)} \]

Measurement of betatron tune Q:
Maximum of BTF

\[ H(\omega) \]

Observation of Transverse beam Oscillations
- E.M. pickup
- resonant BPM
- others
Simple example: FFT analysis

$G(\omega) == \text{flat}$
(i.e. excite all frequencies)
Made with random noise kicks

Measure beam position over many consecutives turns
apply FFT $\rightarrow H(\omega)$
$\text{BTF} = H(\omega)$
Network Analysis

1. Excite beams with a sinusoidal carrier

2. Measure beam response

3. Sweep excitation frequency slowly through beam response
Time Resolved Measurements

- To follow betatron tunes during machine transitions we need time resolved measurements. Simplest example:
  → repeated FFT spectra as before (spectrograms)
Principle of PLL tune measurements

This PLL system looks to the 90 deg. point of the BTF.

Beam

Read VCO
Frequency = tune!
At regular Time intervals

VCO
Voltage controlled oscillator
A sin(ωt)

BPM
B sin(ωt+φ)

Phase detector
AB sin(2ωt +φ)cos(φ)

Frequency control:
ABcos(φ)

Lowpass

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Illustration of PLL tune tracking

PLL will lock on 90° point of BTF;
Example of PLL tune measurement

In this case continuous tune tracking was used whilst crossing the horizontal and vertical tunes with a power converter ramp.

Closest tune approach is a measure of coupling

$q_h - q_v$
Sequence of the exercises

- 11 detailed exercises: printed booklet
- Objectives from
  - familiarization with the setup
  - measurement of BTF
  - NCO design
  - phase detection
  - closure of the PLL
  - amplitude regulation
- All exercises (designs) ready and tested
- Minimum expectation: students load ready designs and understand them
- Maximum expectation: students find the bugs in our designs and correct them
Lab setup
Example: Exercise 2
« Measure BTF using the evaluation board »
Lab setup

Use PC as oscilloscope and signal generator.
Practical instructions:

• No drinks/food/cigarettes in the labs please
• Get together in teams of two: Recommended: similar level of competence
• Labs are open in the evening: Everybody is invited to come back to his working place after dinner in order to play a little with the setup

• Now:
  define 48 + 48 students for FPGA/DSP courses