Conceptual Piezo Control System Design for European XFEL

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Abstract

XFEL accelerator will be composed of superconducting cavities. Pulsed operation of high gradient cavities results in dynamic Lorentz force detuning. The cavity can be tuned to a resonance frequency using Piezo Compensation System. The main goal of this presentation is to give short overview of conceptual piezo control system design foreseen for XFEL accelerator. The system is designed to be compatible with μTCA hardware architecture chosen for LLRF control. The single piezo module will consists of 16 driving and sensing channels. The system will allow piezo pulses generation with RF pulse field repetitions up to 25 Hz. The build-in switching circuitry will allow changing the piezo actuator and sensor functionality during real time operation of the accelerator. The piezo module will be dedicated for both pulsed and continuous wave operation modes foreseen for XFEL. What is more, the first laboratory tests of the prototype system are demonstrated and discussed.

System Requirements

- **General parameters:**
  - Operation type: synchronous, triggered by trigger signal
  - Maximum repetition rate: 25 Hz
  - Trigger resolution: < 1 μs
  - Channel number: 16
  - Power supply: 230 V, 750 W, Power dissipation < 150 W with maximum excitation at all channels for 10 Hz operation, < 400 W for 25 Hz operation
  - Dimensions: 19 inch, 3U

- **Control interface:** serial link, at least 100 Mb/s,

- **Driver output parameters:**
  - Output load $R_{\text{load}}$: capacitive, $(2 \div 6) \mu$F
  - Output voltage range: ±85 V
  - Output bandwidth (3dB): DC + 300 Hz (with maximum amplitude and load), for 10% of max. amplitude the output bandwidth is DC + 3 kHz
  - Noise level: < 3 mV rms (corresponds to 0.1 Hz) SNR < -74 dB
  - Channel crosstalk: XT < -60 dB between any channels
  - Overvoltage protection: $U_{\text{min/max}} = \pm 120$ V (clamping level)
  - Overcurrent protection: $I_{\text{max}} < 1.5$ A
  - Current slew rate protection: $|d(I)/dt|_{\text{max}} < 10$ mA/μs
  - Monitoring outputs: voltage type, signal range: ±2.5 V, for current monitoring output 1 V must correspond to 1 A

- **Sensor input parameters:**
  - Input impedance: $Z_{\text{in}} = 1$ kΩ
  - Input voltage range: ±2.5 V
  - Input bandwidth (3dB): DC + 1 kHz
  - Noise level: SNR < -70 dB
  - Sampling frequency: > 3 kHz (better 10 kHz)
  - Channel crosstalk: XT < -60 dB

Block Diagram

Lab Tests

- **$f_{\text{sampling, min}}$:** 156 kHz
- **$f_{\text{sampling, max}}$:** 10 kHz
- **$f_{\text{input}}$:** 300 Hz

- **$P_{\text{max}}$:** 240 W
  - 16x power amplifiers driven simultaneously ($R_{\text{load}} = 5 \mu$F)

- **Bipolar mode**

- **Unipolar mode**

Prototype System

Prototype Piezo Compensation System has been designed, fabricated and laboratory tested. It was capable of simultaneous driving of 16 power amplifiers connected to 5 μF capacitance load. 16 piezo drivers have been successfully operable with both bipolar and unipolar control schemes. During the experiment the power supply unit requirements have been estimated. The sampling frequency of more than 10 kHz per piezo sensor channel has been achieved using one channel analog to digital converter and additional multiplexer circuit. The presented results will be used as remark for the target piezo module design.

Conclusions

17-20 October 2011 DESY, Hamburg