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LLRF electronics for the CNAO synchrotron

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The Italian National Centre for Oncological hAdrontherapy (CNAO) is undergoing its final construction phase in Pavia and will use proton and carbon ion beams to treat patients affected by solid tumors. At the hearth of CNAO is a 78 meters circumference synchrotron, capable of accelerating particle up to 400 MeV/u with a repetition rate of 0.4 Hz. Particle acceleration is done by a unique VITROVAC load RF cavity operating at a frequency between 0.3 and 3MHz and up to 3kV peak amplitude. This paper describes the Low Level RF electronics developed for this synchrotron.

Summary

A complete digital LLRF system has been designed at LPSC in order to control the CNAO accelerating cavity. The two main tasks of the electronics, cavity control and beam control, are assigned to two independent dedicated Digital Signal Processors (DSP). A Field Programmable Gate Array is managing digital I/Os, ADCs readout, memory access and is performing fast digital signal processing tasks such as I/Q demodulation of the cavity and beam pickup signals.
The RF cavity frequency is generated by a Direct Digital Synthesizer (DDS) which amplitude is digitally controlled by a logarithmic amplifier. Two other DDS are used for the generation of a sampling clock (sixteen time the cavity frequency) and a general purpose external synchronization signal (variable phase).
The LLRF electronics is connected to the CNAO control-command system thanks to 5 high speed serial links in order to transfer acceleration cycle parameters (Frequency, Amplitude, Cavity tuning current, beam position, etc ...). A slow control interface is also provided thanks to an Ethernet microcontroller board developed at LPSC. This Ethernet slow control link is used for in situ DSP programming and FPGA configuration. It also provides access to the parameter tables of the beam and cavity DSP and enable data retrieval of the embedded data acquisition system that stores all input and output signals during a given acceleration cycle.
Although specifically designed for the CNAO synchrotron, the versatility of the architecture and the fact that the board can be remotely configured and programmed very easily make it usable on different accelerators. First tests of the beam control ability of the system have thus been done on the PS Booster at CERN and will be presented on this paper in addition to electronics architecture, lab measurements and test results on the CNAO cavity.

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