A Cavity Synchronization System For Heavy Ion Synchrotrons Based on DSP, DDS and FPGA Technology

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FAIR

Abstract

A cavity synchronization system has been realized which allows the synchronization of the gap signals of different cavities. The system is designed in such a way that the cavities may run at different harmonics. In future it will also be possible to synchronize the cavity with the beam, i.e. to realize closed-loop beam phase control.

In order to fulfill these requirements, the overall system is based on different scalable modules which can flexibly be used in completely different applications. The key modules are a DSP system with IF signal preprocessing, an FPGA Interface Board (FIB) and a DDS unit.

These key modules are described in the following. Furthermore, the status of the following applications is reported:

- Digital cavity synchronization for single-harmonic operation
- Dual harmonic operation

Finally, an outlook to other applications is given.

DSP System

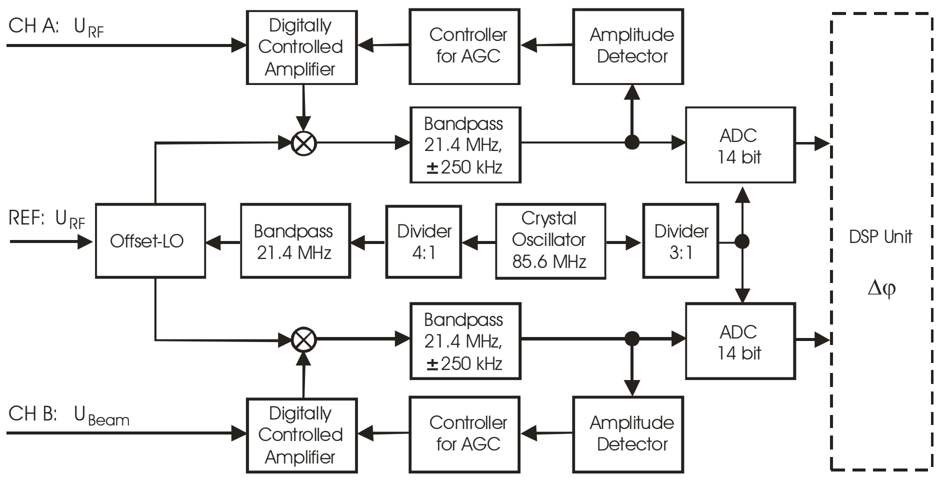

Fig. 1: Block diagram of DSP-based phase detector [1]

The DSP subsystem is used for high-precision phase and amplitude detection and for fast closed-loop control algorithms. It includes analog preprocessing in the IF range, ADC and DAC modules, suitable digital interfaces and comfortable diagnostics features. The DSP system consists of commercial components delivered by Sundance (SMT374 with two TMS320C6713 DSPs, SMT370 with ADC AD664 and DAC AD9777). All modules used for IF signal processing were developed at GSI. The mixer modules incorporate a digitally controlled amplifier AD8321 and crystal filters XF-214S131.

FPGA Interface Board and its Applications

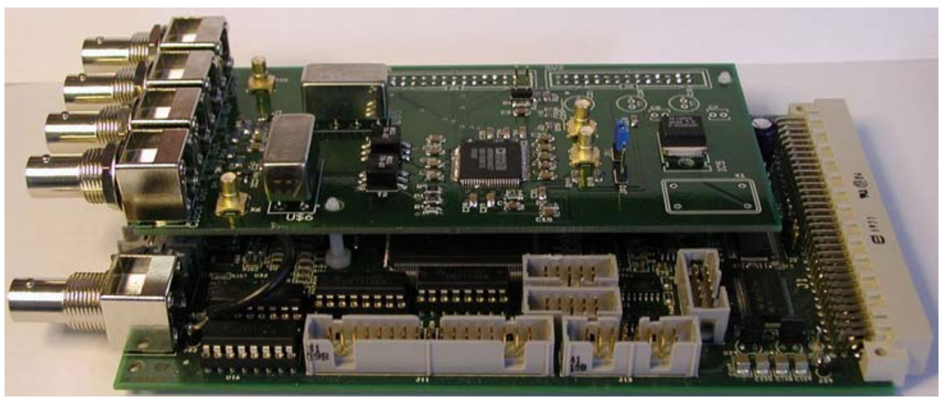

Fig. 2: FPGA Interface Board (FIB) with DDS piggyback module

The FPGA Interface Board (FIB) provides an interface to the central control system and several other interfaces which are used as a standard in the GSI synchrotron RF group. The interface protocols are realized by an FPGA (Altera Cyclon, EP1C6Q240C8) which allows one to implement routing, control and signal processing applications.

DDS Unit

The DDS unit is used for the generation of RF master signals and can also serve as actuator in closed loop RF control systems. Furthermore, it will be used in future to realize the functionality which is currently performed by an analog offset LO (local oscillator). The DDS module is realized by combining a FIB with a dedicated piggyback PCB (see Fig. 2, DDS chip AD9854).

Cavity Synchronization System

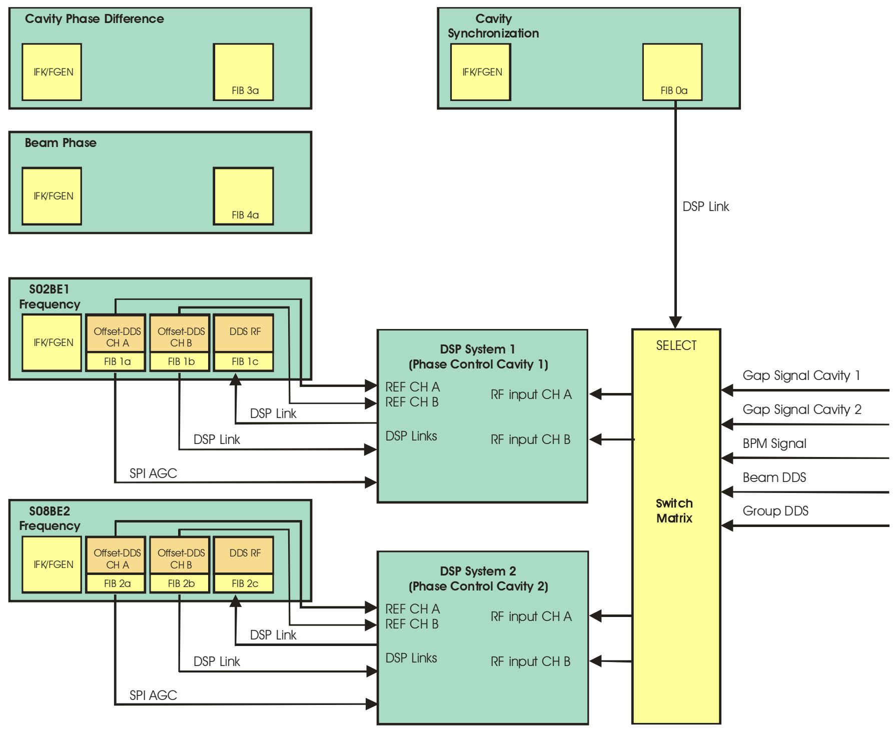

Fig. 3: Block diagram of planned overall system implementation

Fig. 3 shows the planned system configuration for the heavy ion synchrotron SIS18. The blocks on the top and on the left side represent the crates (so-called "devices") which receive ramp data or control information from the central control system. The FIBs are used in a flexible way for different purposes. They exchange information using optical links (not shown in Fig. 3)

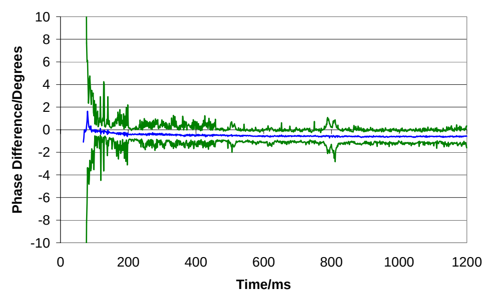

Fig. 4: Phase difference of gap signals established by closed-loop control

Fig. 4 shows a measurement for the phase difference between the gap signals of the two SIS18 cavities when the cavity synchronization loop is closed (green: maximum and minimum, blue: average). A maximum phase difference of ±2° is reached. The measured threshold of the closed loop is below 50V per cavity. The larger deviations at the beginning are due to the speed of the AGC which can easily be improved in future.

In Fig. 5, a screenshot of the graphical user interface (GUI) is presented. This GUI enables the user to monitor the status of the DSP system and to perform data acquisition. Data acquisition does not have any impact on the real-time closed-loop control. The DSP system is not dependent on the proper operation of the host PC; the host PC is solely needed for diagnostics purposes. Since the GUI is based on a standard Microsoft Windows® operating system, its functionality can easily be extended and remote operation via Ethernet is also possible.

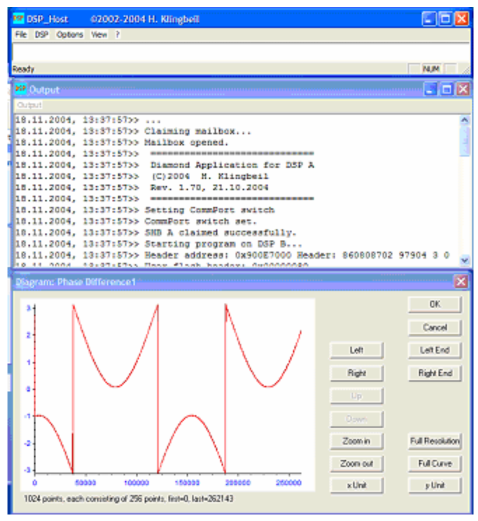

Fig. 5: GUI for diagnostics purposes

Outlook

Up to now, the cavity synchronization is a prototype system which was tested successfully during machine experiments. The next step is to put the system into standard operation. Afterwards, dual harmonic operation and beam phase control for damping coherent dipole modes of oscillation will be implemented as shown in Fig. 3.

References

[1] H. Klingbeil: A Fast DSP-Based Phase-Detector for Closed-Loop RF Control in Synchrotrons, IEEE Trans. Inst. Meas., Vol. 54, No. 3, June 2005, p.1209-1213.

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