A DIGITAL BASEBAND LOW LEVEL RF CONTROL FOR THE P-LINAC TEST STAND AT GSI*

R. Eichhorn#, A. Araz, U. Bonnes, F. Hug, M. Konrad, P. Nonn, TU Darmstadt, Darmstadt, Germany
R. Stassen, FZJ, Jülich, Germany
G. Schreiber, W. Vinzenz, GSI, Darmstadt, Germany

Abstract

During the redesign of the low level RF system for the S-DALINAC, a baseband approach was chosen. The RF signals from/ to the cavity are converted into the baseband via I/Q Modulators/ Demodulators. The advantage of this design was realized lateron, as adaption of other frequencies becomes rather easy. The system, originally designed for 3 GHz superconducting cavity in cw operation is currently modified to control a 324 MHz room temperature CH cavity in pulsed operation. We will report on the rf control system principle, the required modifications and first results.

INTRODUCTION

The new FAIR facility, currently under construction at GSI in Darmstadt, Germany will provide high intensity proton and ion beams for new experiments in the fields of nuclear and particle physics. Thereby one main feature of the FAIR facility will be the production of cooled antiproton beams. In order to achieve a high intensity within these beams the energy and intensity of the initial proton beam has to exceed the limits of the existing UNILAC accelerator currently used as injector for all beams at GSI [1]. Therefore the design of the FAIR facility provides a new injector linac for protons. This new p-LINAC will deliver protons with an energy of 70 MeV and a beam current of 35 mA to the following SIS-18 synchrotron [2]. The p-LINAC will work at a frequency of 324 MHz in pulsed operation at a repetition rate of 5 Hz. The estimated time structure of one rf pulse is shown in Fig. 1.

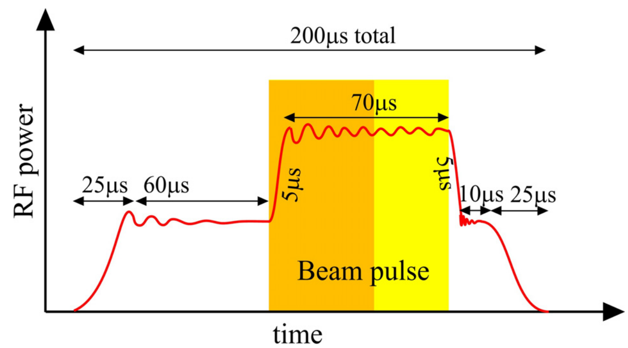

Figure 1: Time structure of a rf pulse in the new p-LINAC.

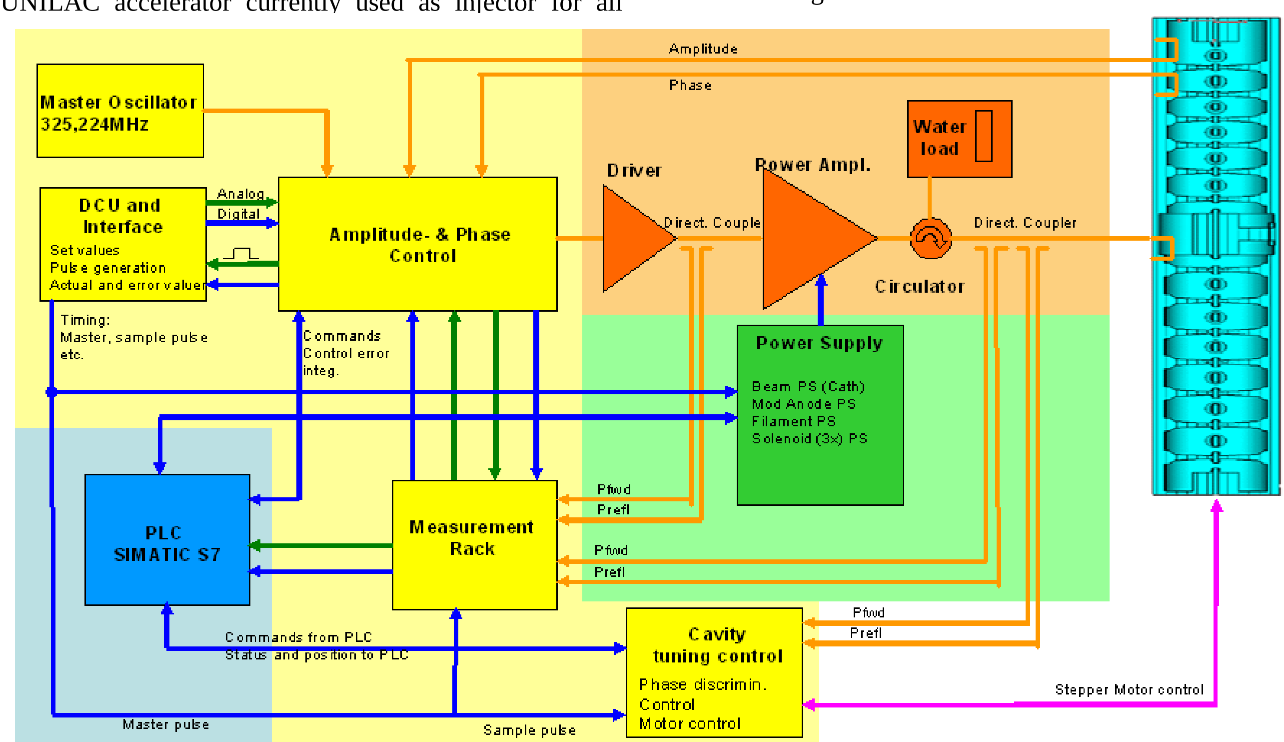

Figure 2: Design of the p-LINAC test stand planned at the GSI. The part concerning the control system discussed within this paper is printed in yellow.

* Work supported by the BMBF through 06 DA 9024 I
# eichhorn@ikp.tu-darmstadt.de

Within the beam pulse the amplitude and phase of the rf cavities have to be controlled strictly in order to achieve a high beam quality. The requirements of the amplitude and phase stability for the rf control system are given in Table 1.

Table 1: Stability Specifications

Relative amplitude stability	$\Delta E/E$	$\pm 1\cdot 10^{-3}$
Phase stability	$\Delta\varphi$	$\pm 1°$

The digital baseband low level control system of the S-DALINAC already meets these requirements for a superconducting 3 GHz cavity in cw operation [3]. For the p-LINAC this system will be further developed for a 324 MHz room temperature cavity in pulsed operation. This new control system will be also part of the p-LINAC test stand containing a test cavity, power supplies and amplifiers which will be built at GSI (see Fig. 2). The next section will introduce the S-DALINAC control system and show the possibility to extend this system to other operating frequencies.

S-DALINAC RF CONTROL SYSTEM

Layout

A detailed description of the S-DALINAC control system can be looked up in [3]. Within this paper we will give a short view on the main topics of this system. The digital S-DALINAC low level control system is designed for a 3 GHz superconducting cavity in cw operation. It consists of two main parts (see Fig. 3). In the RF board the 3 GHz signals are converted down to the baseband and not to an intermediate frequency like elsewhere [4]. The low frequency signals, amplitude and the demodulated I/Q phasors are transmitted as analogue signals to the new developed FPGA board, where they are digitized and processed.

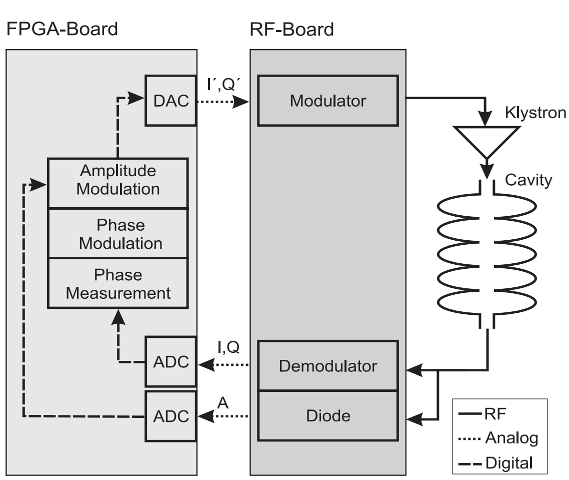

Figure 3: Layout of the S-DALINAC RF control system.

After the algorithm is applied, the signals are transformed to analogue again and transferred to the RF board where they are modulated onto the 3 GHz LO frequency again to drive the cavity.

FPGA Board

Following the mainstream in RF control system design for the new low frequency module, a digital solution based on an FPGA (Xilinx Spartan 3) has been developed. The great flexibility of a digital solution is one of the most important features of this solution as it enables to change control algorithms quickly without changing the hardware. The algorithms are developed offline using VERILOG and then flashed into the FPGA to be used intantly.

The developed module for the S-DALINAC control system is shown in Fig. 4. The FPGA has a main clock of 80 MHz, which allows to digitize and to process the analogue low frequency signals from the RF board with a sampling rate of 1 M samples per second. The ADCs have a measured resolution of 16 bits. The implemented USB 2.0 interface is used for an extensive diagnostics of the control loop. It is possible to read out up to eight parameters of the control loop in real time without data reduction allowing an extensive diagnostics of the control system during development and finding the best set of control parameters for the loop. These control parameters are set via CAN-bus interface.

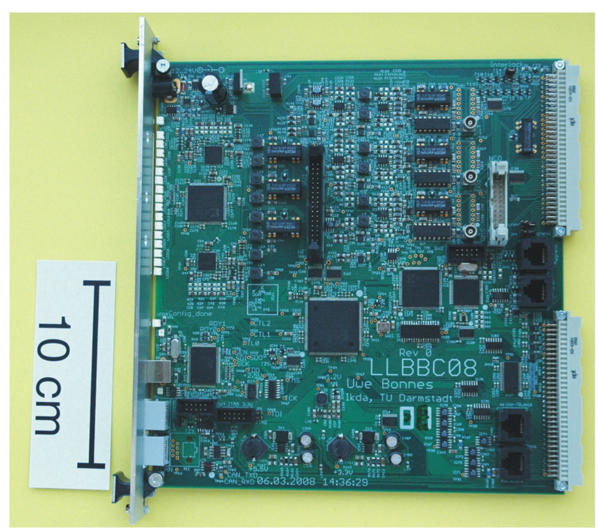

Figure 4: Picture of the S-DALINAC FPGA board.

RF Board

The new developed S-DALINAC rf-board is built out of RO4350, a high frequency capable rodgers material. It consists of highly integrated, commercially available wifi components with low noise and excellent stability against temperature variation. The board is shown in Fig. 5. It converts the 3 GHz signals of the cavitiy down to the base band in a I/Q-demodulator mixing the rf signals with the reference of the LO. The amplitude of the rf signals is measured in a detector diode, which provides a higher accuracy of power detection than the I/Q-vector, which is used for the phase detection. The analogue base band signals are transferred to the FPGA board via cable. The processed signals from the FPGA are transformed back to analogue on the FPGA board and sent back to the rf board where they are modulated onto the 3 GHz reference in a I/Q-modulator.

The rf signals are processed inside the rf board only, so an extension on other frequencies turned out to be rather easy. It is possible to keep the low frequency part with the FPGA as it is and do the adaption on a new frequency just by changing the modulators, demodulators and the couplers. Doing so a 6 GHz version for a cw copper cavity, operating inside a harmonic bunching system, was built and tested [5], as well as a 1.3 GHz version for a sc cavity.

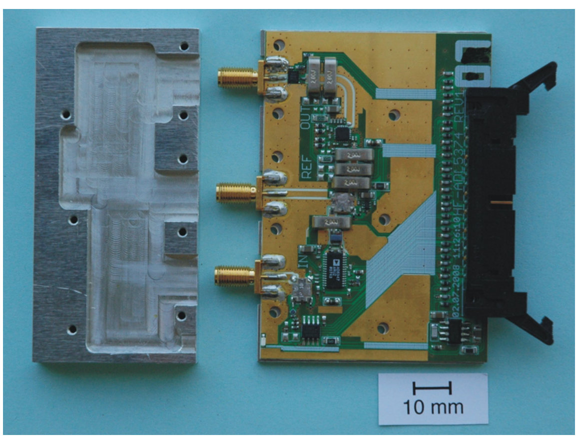

Figure 5: Picture of the S-DALINAC 3 GHz rf board.

P-LINAC RF-CONTROL SYSTEM

RF-board

For the p-LINAC a new 324 MHz rf-board has been developed at TU Darmstadt applying little changes at the design of the S-DALINAC 3 GHz rf-board (see Fig. 6). The board is currently tested on fabrication errors. To benchmark the new 324 MHz rf board and to estimate its use on a pulsed cavity, a cavity simulator is needed until the p-LINAC test stand isn't available yet.

Real-time Cavity Simulator

This real-time cavity simulator will provide another considerable advantage as it will be capable of simulating a beam loaded cavity what won't be possible at the p-LINAC test facility. Inside the cavity simulator the cavity will be characterized by either simulated or measured parameters which allows testing the control system for cavities which are still in the designing process. In addition it is possible to describe the amplifiers and couplers as well. The cavity simulator will be built of a commercial available Lyrtech® FPGA module which has a high signal resolution of 14 bit in 8 channels and allows a sampling rate of up to 105 MSPS. The hardware is ordered and will be delivered within the next month. It will be programmed with MATLAB/Simulink using a model based design kit. The algorithm used inside the FPGA can be programmed via a graphical user interface and be moved into the FPGA directly.

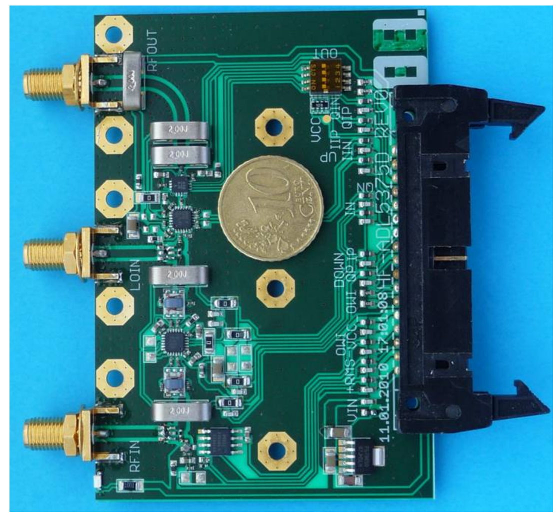

Figure 6: Picture of the p-LINAC 324 MHz rf board.

SUMMARY AND OUTLOOK

The new low level rf control system developed for the S-DALINAC can be adapted easily to the 324 MHz operating frequency of the p-LINAC for FAIR at GSI by changing the rf part of the system and provides the required amplitude and phase stability already. A new 324 MHz rf board has been developed and is tested currently. For testing the control system in future a real-time cavity simulator will be built at TU Darmstadt. This cavity simulator can be used for simulating different types of cavities and the amplifier characteristics as well as beam loaded cavities in future.

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