# Controller for RF Stations for Booster of NICA Project

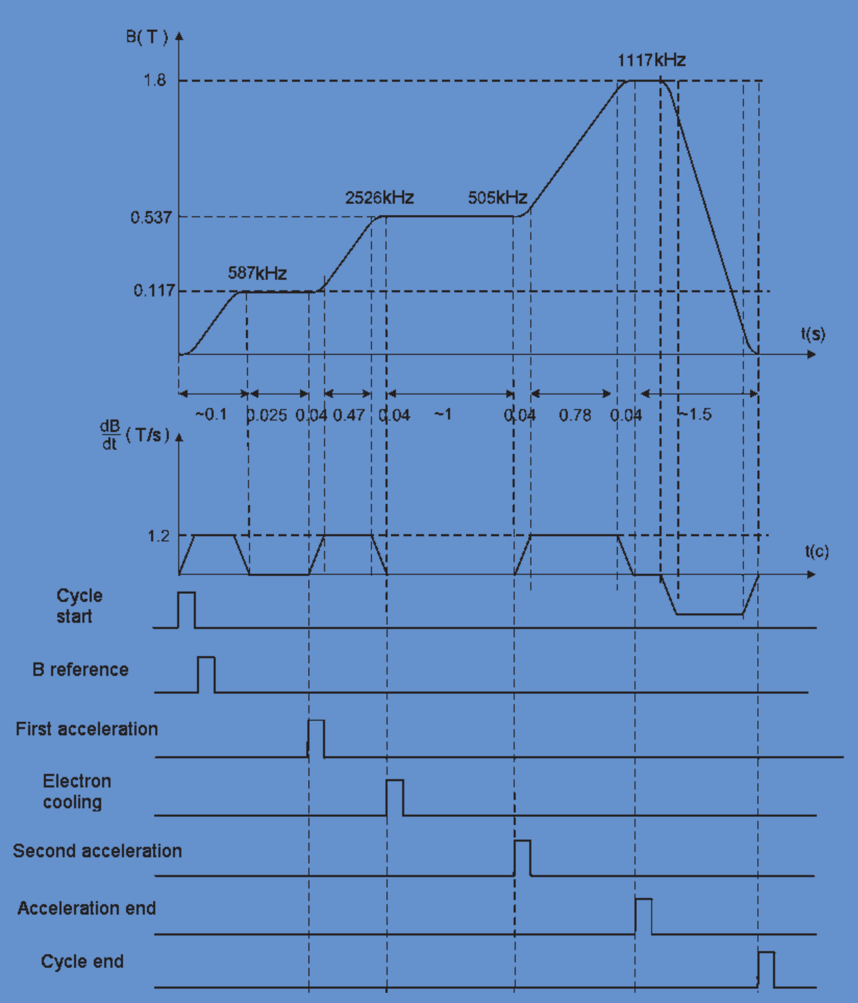
G. A. Fatkin[1,2] , A. M. Batrakov [1], I. V. Ilyin[1], M. Yu. Vasilyev[1,2]
[1] Budker Institute of Nuclear Physics, Novosibirsk; [2] Novosibirsk State University, Novosibirsk
E-mail: G.A.Fatkin@inp.nsk.su

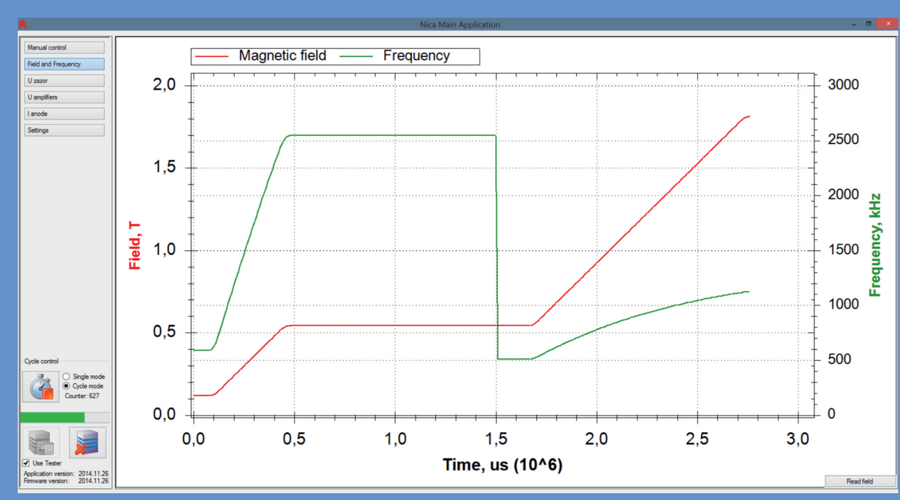
BINP, Russia

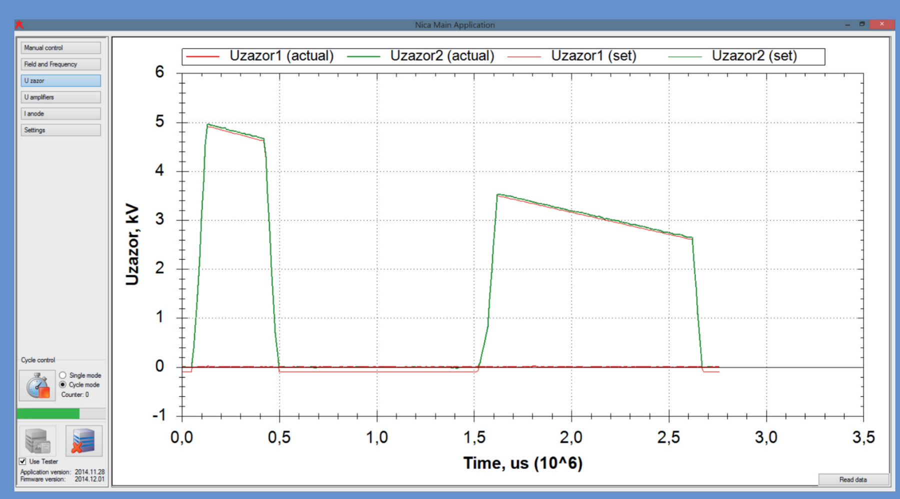
## Introduction

NICA (Nuclotron based Ion Collider fAcility) is an accelerator complex, which is being built in JINR (Dubna, Russia). Control system of the RF stations of Booster is described. Intellectual Controller and Tester modules are presented. Controller measures magnetic field using induction coil and provides corresponding real-time tuning of frequency according to a non-linear law with 20 µs period and better than $5\cdot10^{-5}$ accuracy. Controller also allows setting up and monitoring several parameters of RF stations. The tester module that generates a sequence of events and signals imitating acceleration cycle is alo presented.

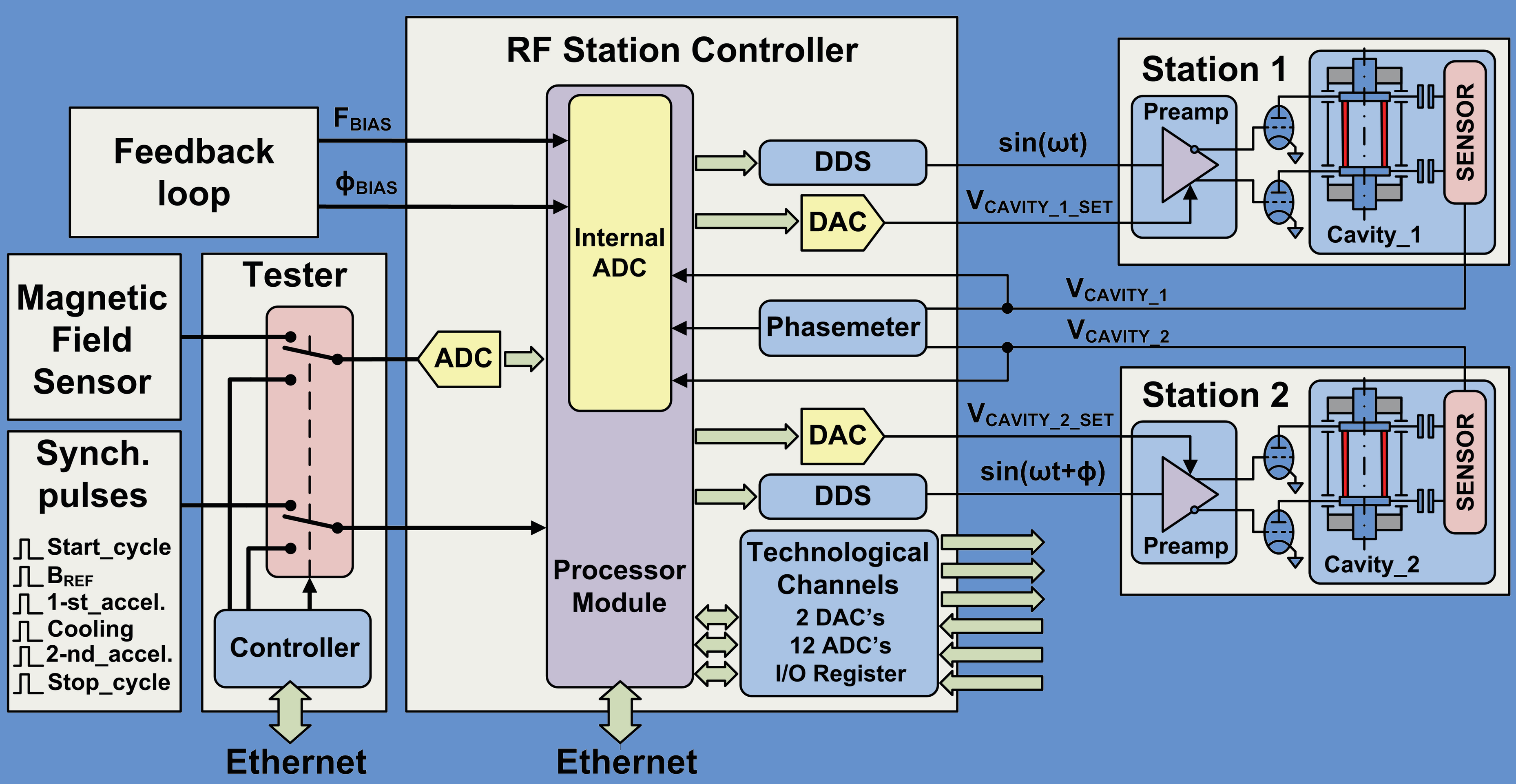
## Acceleration Cycle Time Diagram




## Control Architecture

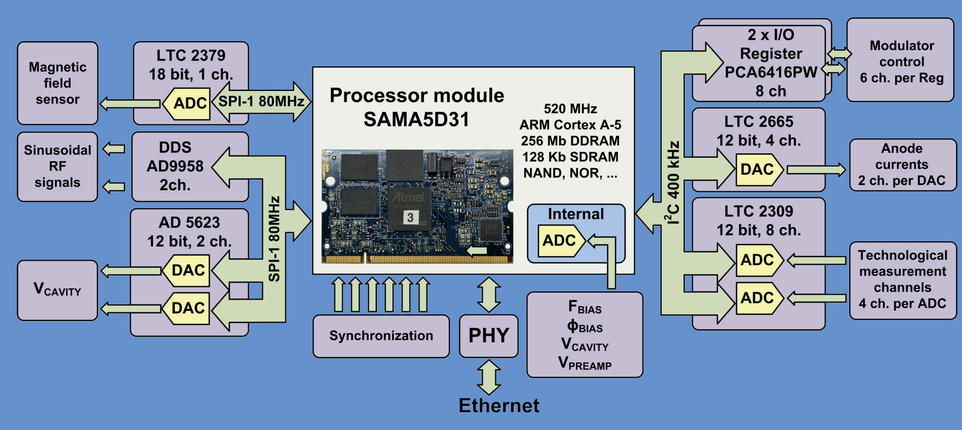



## Controller signals

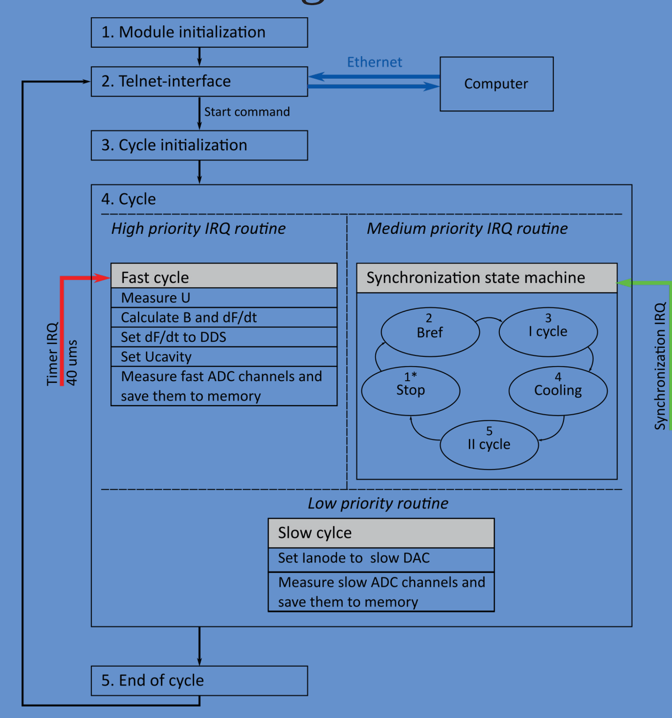
| Signal | Channels | Sample rate | Resolution |
|---|---|---|---|
| **Controls** | | | |
| Master frequency | 2 | 25 kHz | 24 |
| V cavity | 2 | 25 kHz | 12 |
| I anode | 2 | 500 Hz | 10 |
| Synchonization | 7 | N/A | N/A |
| **Measurements** | | | |
| Field Sensor | 1 | 25 kHz | 18 |
| V cavity | 2 | 25 kHz | 12 |
| Phasemeter | 1 | 25 kHz | 12 |
| Phase bias | 1 | 25 kHz | 12 |
| Frequency bias | 1 | 25 kHz | 12 |
| V preamplifier | 2 | 500 Hz | 12 |
| I anode | 4 | 1 kHz | 12 |
| V rectifier | 6 | 1 Hz | 12 |
| V filament | 2 | 1 Hz | 12 |

## Controller Module

Hardware Structure




Program Structure




We tried to use realtime Linux, but finally had to use bare-metal approach to achive necessary precision and cycle time (40 us). Multi-core processor could help!

## Frequency Sweep Approach

$$f(B) = K\frac{aB}{\sqrt{b+CB^2}}$$

Instead of integrating the magnetic field signal

$$B(t) = \alpha\int_0^t U dt$$

How to calculate f(B)?

We differentiate the formula for frequency

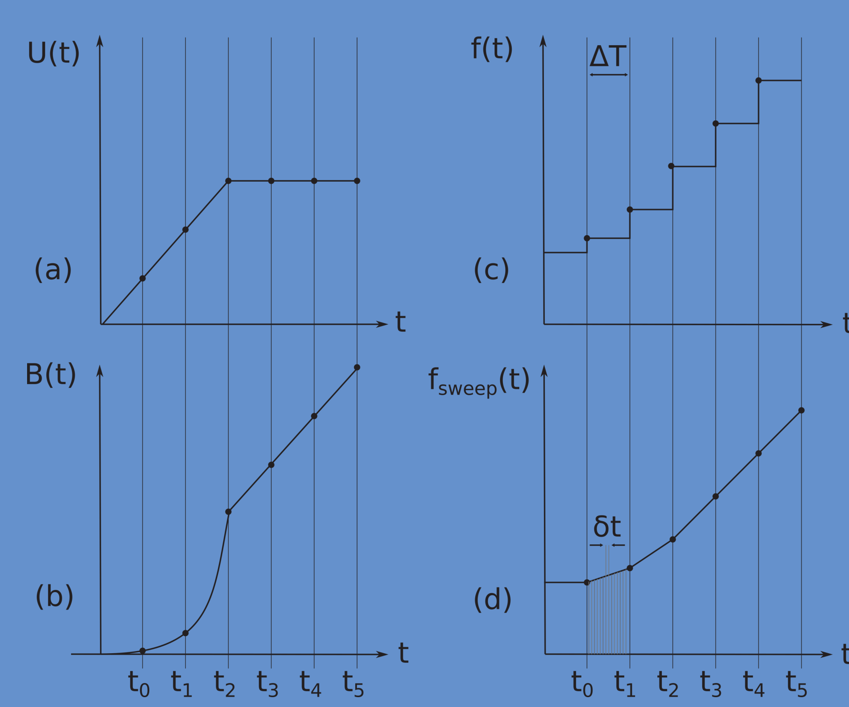
$$\frac{df}{dt} = \frac{df}{dB}\frac{dB}{dt} = \frac{f}{B}\left(1-\frac{C}{K^2a^2}f^2\right)\alpha U$$

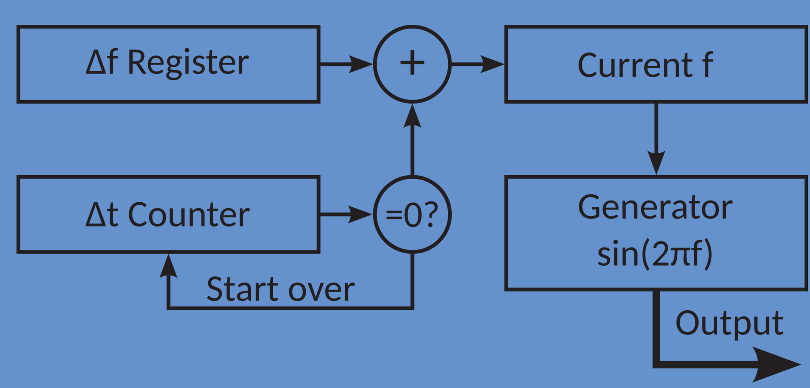
Then we use signal from induction magnetic field sensor U to calculate derivative. Using DDS frequency sweep mode with df/dt we get superior accuracy even with larger cycle times.

$$B_i = B_{i-1} + \alpha U \Delta T$$

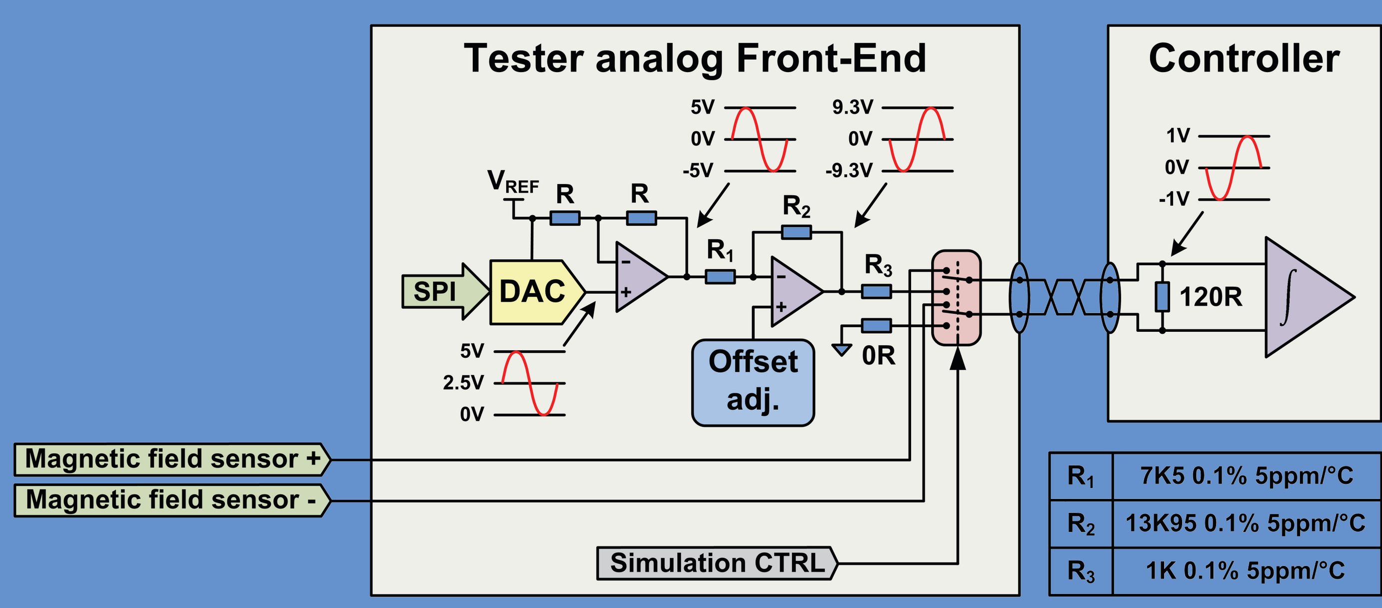
$$\delta f_i = \frac{f_{i-1}}{B_{i-1}}\left(1-\frac{C}{a^2K^2}f_{i-1}^2\right)$$

$$f_i = f_{i-1} + \delta f_i \delta t$$




## Tester Module




Tester module is used for generation of a simulated induction sensor signal and synchronization pulses in absence of real installation. Thus we can test our system before Booster is commissioned (planned in 2018). For the operational check of RF stations the Tester has a multiplexer that allows to disconnect controller module from Booster systems and check it's operational capability. In real work, the Tester will be in through-pass mode providing signals from Booster to the controller inputs.

## Interaction with Booster Control System

Both tester and controller modules are managed over the Ethernet interface using text-based command protocol over telnet. This allows easy integration into Tango-based Booster Control System. RS-232 interface is provided for reprogramming and debug.

Testing software was developed. It will also serve as a reference for implementation of corresponding modules in NICA Booster control system.

## Conclusion

Controller and tester modules were designed manufactured and tested in working conditions with RF stations generating high voltage. Usage of SAMA5D31-CK board allowed to significantly reduce prototyping time. New approach for frequency tuning was devised. Overall measured innaccuracy using frequency meter is better than $1.4\cdot10^{-5}$. Beam feedback module would be produced and incorporated to the LLRF control system after NICA Booster comissioning.