# THE CONTROL SYSTEM OF THE CRYOGENIC COMPLEX FOR THE SUPERCONDUCTING RF SEPARATOR AT IHEP

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## ABSTRACT

The superconducting RF separator will be used for separation of kaons for the experiments at the OKA setup [1] at IHEP. A cryogenic complex which is capable to provide liquid helium with the temperature of 1.8K as well as liquid nitrogen is required for the separator. We report on architecture, hardware design and software development for the control system of the cryogenic complex.

## ARCHITECTURE

The separator consists of two deflecting niobium cavities that produce strong oscillating electrical field. The distance between cavities housed in cryostats is 76 m. Their cooling is provided by one large commercial helium refrigerator and two small custom heat exchangers, located near cavities. A special cryogenic test facility was built at IHEP for various tests and measurements of the separator and its subsystems [2].

About 300 parameters of the cryogenic complex, including temperature (1.8K…300K), pressure, liquid helium and nitrogen levels and some others have to be measured. The number of commands to be generated and closed loops to be activated is about 300 and 20 respectively.

The architecture of the control system is similar to the control system of the extracted beam lines (including the kaon beam line) [3] at the IHEP U-70 proton synchrotron. Simplified block diagram of the system is shown on Figure 1. It includes the following components:

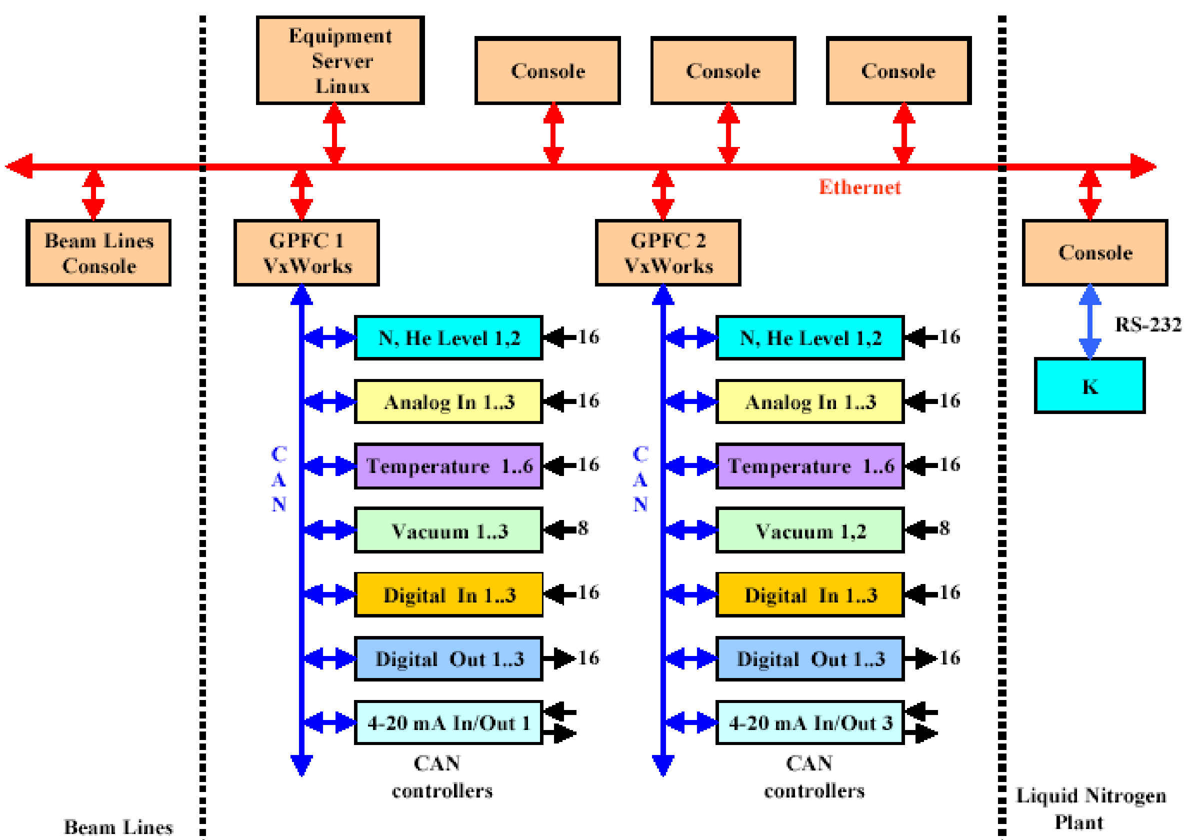


Figure 1: Control System of the Cryogenic Complex for the RF Separator.

- Personal Computers (PC) - at the console level in two Control Rooms (Cryo and Vacuum)
- General Purpose Field Bus Controllers GPFC [4], driving two CAN field buses – at the front-end level, designed as stand alone computers
- I8051 – compatible controllers - at the equipment level.

## EQUIPMENT CONTROLLERS

Equipment controllers are located at a lower level of the control system and provide data acquisition and communication with the front-end level over CAN field bus. The total number of equipment controllers is 50. The controller is built on a modular principle and consists of the main microcomputer board (ADUC 834) and an application specific interface board. RS232 interface simplifies testing the modules on PC. Combining necessary interface boards allows us to assemble controllers for different applications including closed loop controllers generating in particular or 4-20 mA signals. The boards 200 x 110 mm are housed in crates.

SW is written in C. Later on SW for calculations and closed loop controls will be deposited into controllers.

Examples of the controllers are discussed below.

Temperature Measurement Controller

Temperature measurement was the first urgent task in the project because of technical problems in implementation of EPICS. We have designed a resistance measurement module based on ADUC 824 microcomputer with special analog board with 16-channel multiplexor.

Next classes of temperature sensors intended to be used: Allen-Bradly within 2,8…100 K, germanium TSG-2 within 1,9…27 K with accuracy +/-0,05 K, germanium TPK within 3,5…20 K with accuracy +/-0,08 K, platinum TP-100 within 13,8…273 K with accuracy +/-0,01 K.

The total processing time is 100 ms per channel including 35 ms for a current feeding of the sensor. Using a 4-wire connection to a sensor one can reach a precision of the resistance measurement of about 0.1% on a 100 m long communication line . The measurement procedure consists of four steps:

- 15 ms for a feeding of the sensor. Simultaneously an input of the measurement circuit is connected to ground and an offset is stored in the memory
- 20 ms for connection of the sensor to the input amplifier
- 0.5 ms pause for switching the input amplifier
- 50 ms or less discharge of the integrator capacitor on a reference resistor

A limit of the dissipated power in the sensor is being set from the operator console. The module is powered from ~220V supply and consumes about 10W.

### *Vacuum Measurements Controller*

An availability of both medium (0 – $10^{-3}$ Torr) and high (better $10^{-3}$ Torr) custom vacuum sensors (totally 25) stipulated an idea to design dedicated vacuum measuring electronic modules instead of commercial ones.

For "medium" vacuum measurement an analog circuitry provides stable resistance of the thermoresistive vacuum sensor by means of varying a feeding current. Voltage drop on a sensor allows to measure a pressure. For "high" vacuum measurement the calibrated cold cathode sensor is being used. The pressure is calculated based on voltage drop and discharge current measurements. The controller also provides switching between "medium" and "high" vacuum measurement modes and turning power off in case of a failure of the communication line with the sensor in a "medium" vacuum mode or sensor overload in "high" vacuum mode.

Each controller housed in a crate comprises a microcomputer ADUC 834 board, four analog boards for "high" and "medium" vacuum measurements, and one LED indication board.

### *Liquid Helium Measurements Controller*

A liquid helium level sensor is a 400 mm long superconducting wire with warm resistanse of 111.6 Ohm and immersed into liquid helium resistance of 9.6 Ohm. The controller provides a (50…120) mA DC lines to feed the sensor and has a set of comparators on the interface card for calculation of 25%, 50%, 75%, 95% filling of a tank. A measurements of the regulator valve position and regulator valve control over (4-20) mA lines are also provided.

### *Liquid Nitrogen Measurements Controller*

Liquid nitrogen discrete level meter is based on a set of 8 Allen-Bradly TVO thermoresistors (510 Ohm, 0.125W). It was found that the best sensitivity of the sensor can be achieved with the 15 mA DC current provided by the controller.

### *Controllers for Other Measurements*

A pressure measurement controller feeds 8 sensors from separate 15V DC power supplies and allows to measure 1V..5V signals. A controller to measure a temperature of pump motors provides feeding of 15 semiconductor sensors from one 15V DC power supply and measurements of 1V…5V signals. Finally, a controller with digital input/output interface board provides 16 isolated bidirectional channels.

## SOFTWARE

The software of the system at a levels of operator consoles, Linux servers and GPFC is based on EPICS tools [5]. The server on PC with Linux SuSE 7.2 provides loading of the EPICS basic software to GPFC controllers over Ethernet, data archiving, storage of the database of vacuum and temperature sensors, processing and user-friendly displaying of the collected data. The GPFC controllers operating under the VxWorks real-time OS, provide communication with the equipment controller via CAN serial bus.

The process database in the GPFC controllers is identical for both temperature and pressure measurements and contains the records for each measuring unit for the following tasks:

- resistance settings for sensors
- reading of mantissa and exponent values of the resistance
- calculation of conductivity in technical units
- calculation of temperature using the appropriate calibrating tables.

Testing of the joint operation of GPFC controller with two temperature units (32 channels) and two vacuum units for the measurements of “high” and “medium” vacuum (8 channels) have demonstrated a reliable operation at a frequency of 0.5Hz**,** which is sufficient for the cryogenic complex operation.

## CONCLUSION

About 50% of the electronics for the control system has been built by 2005. An integration tests of the cryogenic equipment, electronics and software are underway.

## REFERENCES

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