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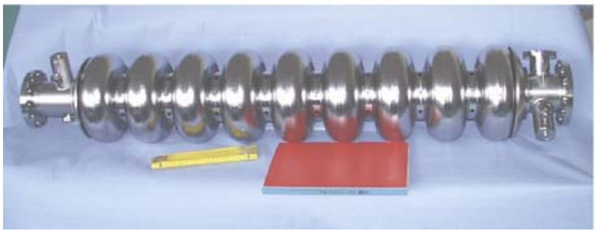

# DIAGNOSTICS FOR THE LOW LEVEL RF CONTROL FOR THE EUROPEAN XFEL

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## Abstract

One of the most important goal of the diagnostic system is to provide the high reliability. This article describes the concept and the proposal for a diagnostics for the Low Level Radio Frequency system for EUXFEL. It enables immediate location of faults and understanding of their causes, tests the functionality of LLRF system, tests each of the electronic boards and connections. The diagnostic system checks different LLRF subsystem components. Hardware, software and database aspect of diagnostic system is presented. The main part of this paper is devoted to the hardware and software specification of the diagnostic.

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## *Abstract*

One of the most important goal of the diagnostic system is to provide the high reliability. This article describes the concept and the proposal for a diagnostics for the Low Level Radio Frequency system for EU-XFEL. It enables immediate location of faults and understanding of their causes, tests the functionality of LLRF system, tests each of the electronic boards and connections. The diagnostic system checks different LLRF subsystem components. Hardware, software and database aspect of diagnostic system is presented. The main part of this paper is devoted to the hardware and software specification of the diagnostic.


## INTRODUCTION

The X -ray free-electron laser EU-XFEL, that is begin planed at the DESY research center will produce high-intensity ultra short X-ray flashes with the properties of laser light. The commissioning of the facility could start in 2012. The total length of the tunnel will be about 2.1 km. The access to the whole electronics placed inside the tunnel will be possible only during the maintenance day (once a month or even more seldom). One of the requirements for the electronic subsystems is the long lifetime and continues work. The LLRF devices will be installed inside the tunnel and exposed on some small level of the radiation. This radiation can cause Single Event Upset (SEU) an active electronic components. Therefore an additional systems redundancy is needed as well as the radiation hardness hardware to ensure the continues work. It is impossible to predict all ways it can fail. Therefore a diagnostic system is needed in order to monitor the hardware and in case of failure switch the system off or run the redundant one. It should also be able to perform offline tests of the device and diagnose the reason of the failure. Because of the scale of the accelerator it is also important to give the information about the placement of the broken part. Due to the complexity of the LLRF system and dependencies between its parts the diagnostic system should monitor as much devices as it is possible. All devices should also provide some hardware and software interfaces through which tests can be preformed. Diagnostic system itself should provide an user interface for experts and operators.

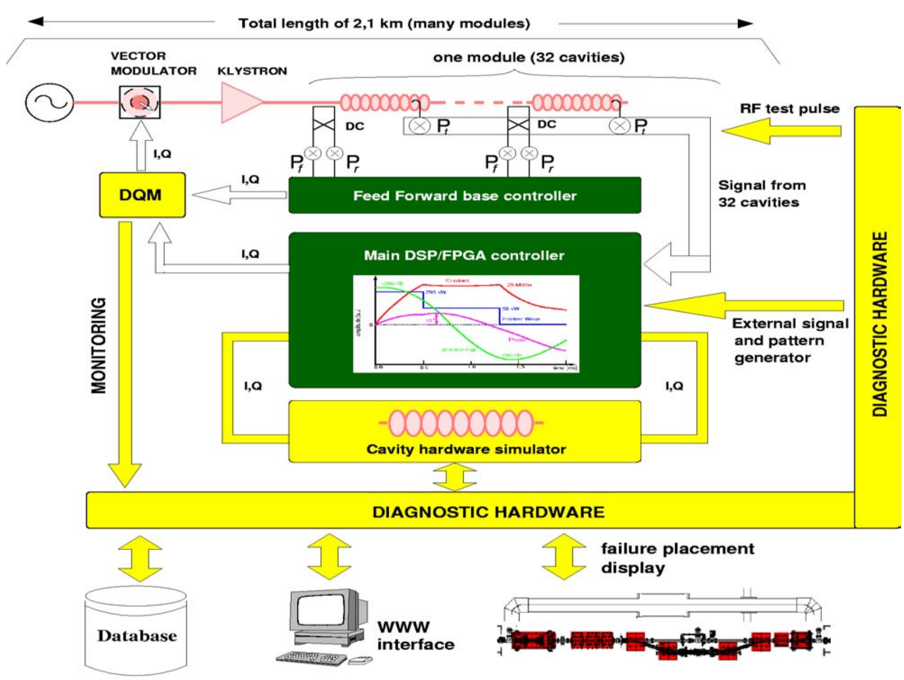


Figure 1: The structure of LLRF and the diagnostic system.

## CONCEPT OF THE DIGNOSTIC SYSTEM

### *Electronics in LLRF*

To design a good diagnostic system means to possess the appropriate knowledge about the LLRF implementation. its structure. The LLRF system will control the electromagnetic field inside the cavity. It consists of probe which measures the field in the cavity, downconverter which decreases frequency from 1.3GHz to 250kHz, in new version to 81 MHz, controller boards with ADCs, DACs, DSP and FPGA [1] chips, timing and trigger distribution system, vector modulator and other components. The system was described in [2]. One module consists of 32 cavities, one vector modulator (VM) and DSP/FPGA controller. The downconverted probe signal is digitized by the ADCs and sent to DSP/FPGA controller. The controller has implemented feed-forward and feedback algorithm. It produces signal I and Q which drive VM. For the output signal calculation the algorithm uses the vector sum electromagnetic field form 32 cavities

### *The Diagnostic System*

The main tasks of the diagnostic software are:

- Monitoring power, temperature, etc.
- Failure detection.
- Perform the complex test of the all electronic boards.
- Examination of the connection between boards.
- Checking logic and algorithm.
- Checking the timing.
- Analysis of the correlation between failures.
- Storing result in database.
- Presentation result of test.

The general concept of the diagnostic system is given in Figure 1. The diagnostic system consists of the hardware and software layer. The signal from the cavity is connected to downconverter and then to DSP/FPGA controller. A simple version of the controller, which allows to use feed-forward tables is running parallel with DSP/FPG controller. The diagnostic system is distributed among different hardware devices. These simple block measures forward and reflected power and can estimate field inside the cavity. The outputs from both controllers are connected to voting system, which can choose the better driving signal. In case any errors, an error signal is sent to the main diagnostic software. At the moment only one controller can drive the VM. In case of error in main controller, another controller will drive VM. The stability driven by the feed-forward controller is slightly degraded but sufficient for operation. It is possible to switch controllers during RF pulse. When main controller is disabled, it is possible to start diagnostic process with the cavity simulator. More sophisticated tests are possible with dummy data. When a problem is diagnosed, it is possible to use modified algorithm and continue the operation. For example if the one ADCs is broken, it is possible continue the operation with the algorithm that estimates the missing data from other sources.

Database is one of the most important elements of the diagnostic system. It stores information about the expected performance, interfaces between boards, placement whole electronics in the tunnel, configuration data, setup files, test results, calibration and system documentation including description of used electronic boards, known problems. Access to database is possible through WWW as well as with dedicated stand-alone applications.

### *Hardware*

The hardware of the diagnostic system consists of:

- dedicated diagnostic and monitoring modules, integrated with the electronic board. This module allows to access any register, memory and chips on the board.
- sources of test signals
- cavity simulator.

The control board for the LLRF is shown in the Figure 2. This board is equipped with the diagnostic module. It includes the FPGA, with implemented DSP blocks, memory, ADCs, DACs, digital inputs and outputs. The PC manages the data transfer from the internal bus to the VME bus. There is also possible to read and write data from the internal bus through Ethernet. This is additional feature, which allows to test the board independently from VME. On the board there is a temperature sensor and a power monitor. The diagnostic module is connected to the internal and VME bus, that allows to access all components on the board. The diagnostic module is equipped with modules, which allows to calculate histogram the given values or count events.
Tests of the particular subsystems may require an additional input signals, which are defined by the user and specific for the particular device. Such a signal, connected to the input of the system (e.g. probe from the cavity) can test the whole chain of devices – from down-converter up to VM.

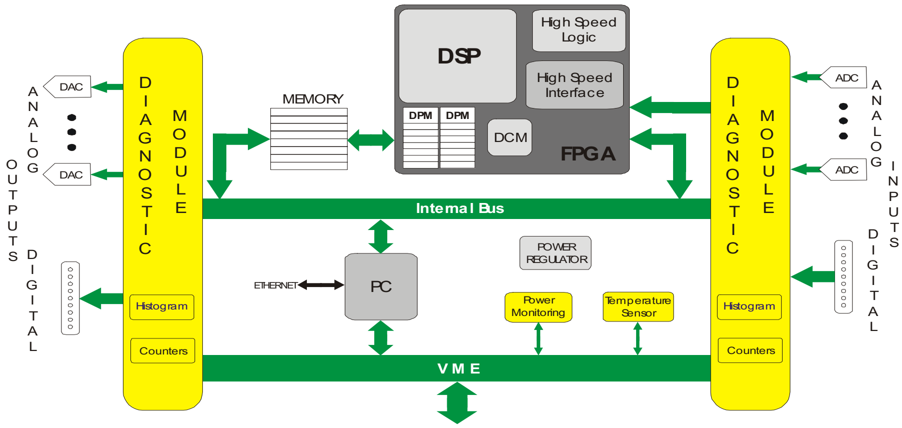


Figure 2: The examples board, control board equipped with diagnostic module.

There are two kinds of test signals:

- *RF test pulse*, allows to examine functionality, logic and connection. The test signal is being put on the input of the system. For the given test signal, diagnostic system knows the proper output signal. This known output signal is being compared with the real output from the tested system. If these signals are not equal this means system failure.
- *signal and pattern generators* allows to examine ADC channels, logical inputs. It can be a part of the bigger chain. Result of tests of the diagnostic system can read immediately from the diagnostic module and compare with predicted values.

The last diagnostic hardware is the cavity simulator, described in [3] and [4]. This device allows to test very precisely the logic, algorithm of the feedback and errors in real time. The cavity simulator can work in a step mode operation. It is very useful option that allows to debug algorithm and the boot file for FPGA step by step. All hardware diagnostic modules allow to test the system on-line, between pulses. This ensures that the possible error can be detected before the next pulse and appropriate procedures can be triggered (switching into redundant system, reconfiguring, etc.) in order to keep the system working.

### *Software and Database*

- The complete analysis of data from the diagnostic modules is done by the software. The diagnostic software controls all the diagnostic hardware through VME bus. Access to VME bus is possible via VME controller – SUN SPARC – or in reasonable cases via Ethernet.

Information about connections, placement of hardware, base addresses of the boards are stored in database. The diagnostic system can be run only from control room, but it is possible to observer diagnose process through web browser (WWW). The configuration data, result of the calibration, and other diagnostic results are also stored in database for further analysis.

### *System Integrity Monitoring*

The important goals of the on-line diagnostic system is to monitor: power and temperature on boards, collect information about events and collecting them in the database. The off-line analyze can correlate an event with data from database. The diagnostic system takes data from input and output of DSP/FPGA controllers, calculated output and compare predicted output witch output from the controller.

## CONCLUSION

An initial of the overall feedback system with a cavity simulator has been demonstrated successful. The diagnostic system allows to maintain LLRF components. Collected diagnostic data can be used by designers, experts to improve the construction and algorithms. Presented solution does not severely increase the cost of the design and manufacturing of the electronic devices, but ensures the longer operation time of the whole system and can safe money and effort used for the maintenance .

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