THE GSI RF MAINTENANCE & DIAGNOSTICS PROJECT

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Abstract
From time-to-time, microcontroller- and FPGA-based LLRF electronics devices need maintenance of firmware and configuration data. The system described here allows this and also long term monitoring of functionality and performance. Both requirements cover measuring devices that operate under a common operating system as well as modules only addressable by means of GPIOs or their programming interface. For large accelerator systems like in the FAIR project, a Web-based remotely controlled system was designed in close collaboration with three industrial partners. To cover the requirements of the extremely different types of participating modules while remaining flexible for future extensions, the system was designed with a maximum of modularity and a strong focus on high reliability and safety. This contribution describes the global structure and the actual status of the RF Maintenance and Diagnostics System. Several types of measuring equipment and LLRF modules such as a phase control loop system and an IF signal pre processing system have been integrated.

INTRODUCTION

In the scope of the FAIR project, several dozens of RF cavity systems will be installed that are distributed over a widely spread area. Cavity systems consist of a large variety of low level radio frequency (LLRF) electronics devices; many of them are programmable devices that require firm- and software updates from time-to-time. Our generic digitally controlled electronics allow different functionalities on the same hardware platform just by loading individual configuration data. Additionally, it is extremely important to gather and save all relevant information about the actual status and performance of all devices for post mortem analysis after failure.

As a conclusion, it will not be possible to meet all the above mentioned requirements manually. Therefore only a remotely controlled system is acceptable. Due to the non time critical operation, advantages of using Ethernet are existing and reliable standards for control and data transmission. Furthermore tracking of system status, tracking of modules after exchange in case of a defect requires an effective and easy to handle management of unique hardware ID, hard- and firmware versions and revisions. High reliability, flexibility and high security standards are essential for the design of the system. Considering standardization aspects reduces diversity and allows less effort in stock keeping and maintenance.

TASKS AND REQUIREMENTS

Major tasks during the design phase of the RF Maintenance and Diagnostics (M&D) System have been:

- The definition of a platform and a global structure for maintenance and diagnostics to cover all requirements of existing components, to keep the flexibility for future extensions and to be open for structural changes.
- Finding solutions to integrate existing but well proven electronics devices into the M&D System to allow maintenance and status tracking. Status information are e.g., statements whether a module is electrically turned on, if the internal power supply works correctly, actual output power, the internal temperature of a module etc.
- The integration of the internally used programming or flash programming standards and being prepared for upcoming new standards in the future.
- The design of a user interface easy to handle that is acceptable for technicians and for experts. Reliability and data security must be guaranteed under all circumstances and at any time.
- Defining a structure for acquiring and visualization of different types of data structures: from polling and block transfer data to streaming data.

Starting with the design of a new internal RF backplane system it was obvious that it could be used as the backbone for the integration of most of the LLRF modules into the RF M&D System [1]. To classify the large variety of modules, a definition of the different hardware types was carried out:

- *Direct Devices* are directly connected to the M&D System by Ethernet like oscilloscopes with common operating systems, or like phase synchronization systems based on industrial personal computers (PC) operating under MS Windows with integrated digital signal processing (DSP) hardware.
- *Direct Backplane Devices* are directly connected to the RF Backplane and can directly communicate with dedicated module that is also plugged onto the backplane. This type of device represents newly developed devices with integrated RF backplane interface. At present no modules with direct access to the backplane have been designed.

- *Adapter Devices:* For modules with no direct connection to the Ethernet or no backplane interface a specific adapter for integration into the RF backplane crates had to be designed.
- *External Devices* are located in separate 19" crates or cabinets and cannot be plugged into the RF backplane crate. For safety reasons and to avoid ground loops an electrical isolation of signal lines for flash programming and data acquisition is mandatory.

Considering the different types of hardware that have to be covered, the following devices had to be designed (see Figure 1):

- The *RF M&D Module* as an interface between the RF Backplane and the M&D system (Ethernet).
- The *RF M&D Adapter Board* as an adapter between the RF Backplane and the LLRF modules with connectors for power supply and the individual programming and signal interfaces. This adapter is mounted together with the specific LLRF printed circuit board (PCB) in an RF cassette that then can be plugged into the 19" backplane crate (in the same way as a future *Direct Backplane Device*.
- An adapter for external devices with electrically isolated individual programming and signal interfaces.

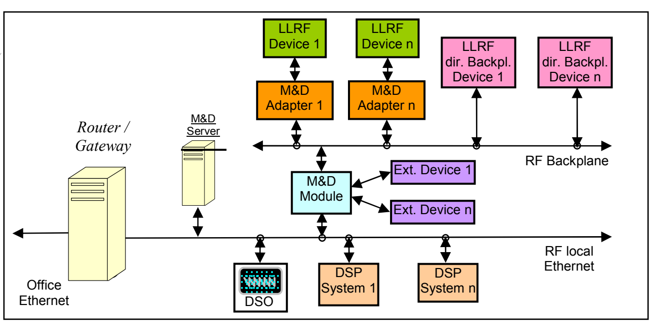

Figure 1 : Integration of different types of LLRF devices into the RF backplane standard.

REALIZATION

Network structure and data base: As already mentioned Ethernet was chosen as the communication layer for operating the system. To be independent from varying performance due to changing network traffic on the office Ethernet and to avoid global attacks to the RF M&D System, a separate local network for interconnecting the cavity electronics systems is installed using only one PC as a gateway to both office Ethernet and the local network (see Figure 2). Properly defined user rights and restrictions in data exchange provide highest possible security standards.

In the final implementation stage the local network will be realized as a virtual network (VLAN) under the GSI network structure that will be more powerful in future.

All relevant data of hardware (unique ID, version and revision number, structure of hardware types) and all software information (version, revision, structure of software packages, storage space for soft- and firmware files) as well as a backup and restore management are realized as services on a M&D server PC. All information is kept in a commercially available database system.

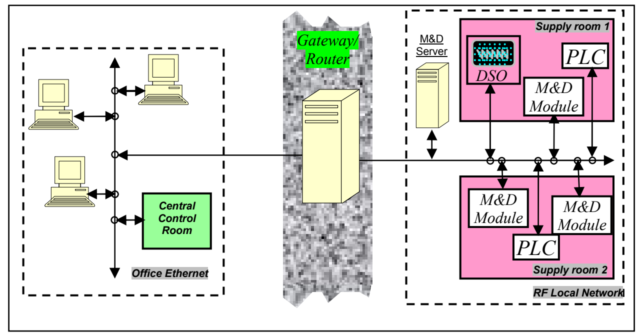

Figure 2 : Network structure.

The M&D System can be accessed by using a web browser and after logging in, all functionality is available.

User Interface: As required, any commercially available browser allows access to the M&D System. In Figure 3 the main menu page of the web interface is displayed. From here, access to the different functionalities is possible:

System Administration for defining of module types and firmware structures, visualization of module trees, adding new modules, etc.

Operations: Selecting of modules, firmware packages and initiation of flash programming processes etc.

Acquisitions: Organization, control and visualization of acquisitions etc.

Maintenance: Adding users, check server status and logs, etc.

Figure 3 : Web interface: Main page of the M&D System.

After adding a module into the M&D System, it is visible in a module tree as it is shown in Figure 4. The internal hardware structure with main and several sub modules is clearly outlined.

In Figure 5 the Operations page for programming a firmware package into the selected hardware modules is illustrated. The desired module in the tree and the desired package for firmware flashing can be individually selected. Possible is for example:

- Flashing of completes module or just a single sub module.
- Flashing of complete or parts of packages.
- Flashing of complete groups of identical hardware types.

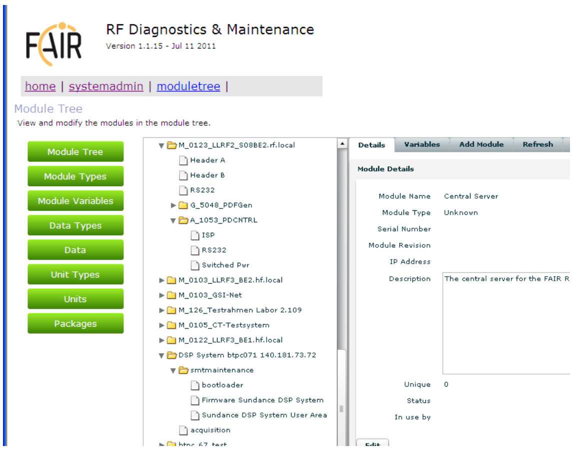

Figure 4 : Web interface: Example for the module tree of registered devices.

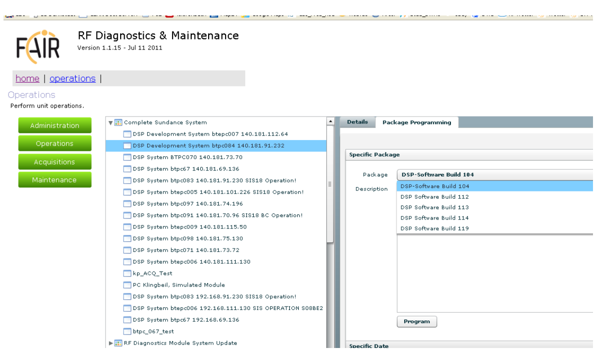

Figure 5 : Web interface: Operations page for package programming into the selected hardware modules.

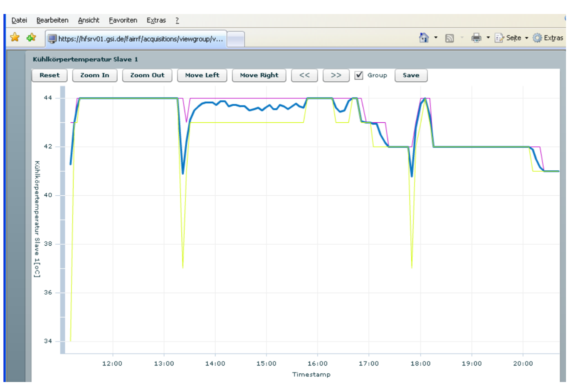

Figure 6 : Web interface: Data acquisitions; record of heat sink temperature of an RF driver temperature.

Hardware modules: The *RF M&D Module* is realized as an RF cassette that is plugged into the RF backplane crate. For high reliability the interface to the backplane is electrically realized in the RS485 standard. Additional front panel connectors can be used for connecting *External devices* (see Figure 7, left hand side).

The *RF M&D Adapter* Board is realized on a PCB with an interface to the RF Backplane and with 3 individually configurable connectors for firmware flashing and 16 general purpose input/output signal lines (GPIO). Up to now, the following standards are supported:

- ISP: In System Programming serial interface for Atmel AT 89C51
- ASP: Active Serial Programming Interface for Altera Flash Memory EPCSxx family;
- JTAG: Joint Test Action Group for Altera MaxII and Max 3000.

Furthermore, 2 power connectors for supplying the related LLRF module are provided (constant and remotely switched supply). Future extensions and standards can easily be added due to the flexible configuration of the programming interfaces.

Figure 7 : RF Backplane and the M&D Module.

CONCLUSION AND OUTLOOK

At the present stage the GSI Maintenance and Diagnostics Systems is in daily use for off-line diagnostics and maintenance of hardware at the GSI accelerator facility and shows excellent functionality, stability and reliability. Examples of firmware flash programming and data acquisition of different kind of hardware confirm the efforts that have been put into design and realization of the system. On hardware side further investigations like a more generic operation of the JTAG interface, analogue channels on the adapter boards and extended alternatives for connecting external devices will take place. The web interface and the data base management will be expanded to provide more user comfort and to automated flash programming procedures after ID, version and revision checks.

REFERENCES

[1] H. Klingbeil, K.-P. Ningel, M. Kumm, "RF Maintenance & Diagnostics System", GSI Scientific Report, 2008.