MODULAR BEAM DIAGNOSTICS INSTRUMENT DESIGN FOR CYCLOTRONS

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Abstract

The Cyclotrons at VECC, Kolkata i.e. Room Temperature Cyclotron (RTC) and Superconducting Cyclotron (SCC) comprise of internal and external Beam Diagnostic systems. These systems provide the beam developer with position, intensity, beam profile, a visual impression of the size & shape of ion beam, and operational control over diagnostic components like 3-finger probe, Beam Viewer probe, Deflector probe, Faraday cup, X-Y slit, Beam viewer etc. [1]. Automation of these components was initially done using customised modules for individual sub-system. An expansion of this facility and various levels of complexity demand modular design to cater easy modification and upgradation. The overall requirements are analysed and modular cards are developed based on basic functionalities like valve operation, probe/ slit/ viewer control, position read-out, Interlock, aperture control of beam line and communication. A 32-bit Advanced RISC Machine (ARM) based card with embedded EPICS is chosen as the master controller and FPGA/ microcontroller is used for functional modules. The paper gives a comprehensive description of all modules and their integration with the control system.

INTRODUCTION

Various upgradations of different sub-systems are being done in both the cyclotrons at VECC, Kolkata are engaged with different kinds of experiments. RTC is getting modernized with new breed of automated beam diagnostics equipments whereas upgradation of internal beam diagnostic system is being done to facilitate internal beam tuning for better extraction at SCC. All the beam regions (injection, acceleration, extraction & external line) are employed with many beam diagnostic stations as per the beam tuning and transportation requirements [2]. The beam diagnostic stations are equipped with different set of components which are either electrical or electro-pneumatically controlled. Development of customized instruments with uniform control scheme, as employed in other sub-systems is required to control and monitor these diagnostic components.

DESIGN CRITERIA

The modular design of the diagnostic control instruments has undergone through several modifications for multiple times due to fast changing and customized requirements. The earlier versions of these instruments had common data and control lines [3]. This design had the restriction of sharing hardware resources due to interfacing compatibility. The recent development introduces an EPICS embedded main controller card, interfacing with other functional modules through dedicated serial lines on backplane. This design has given liberty to the development of individual module while keeping the same software architecture. The developer gets a choice of selecting his own tool chain according to the complexity of functional requirements of the module.

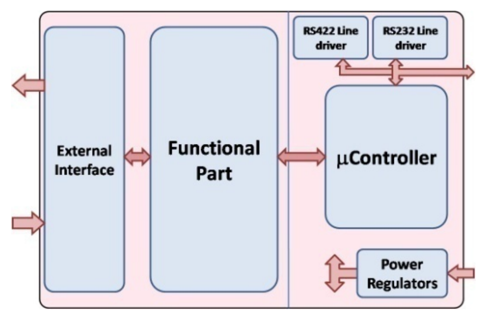

Figure 1: Block diagram of the basic scheme of module.

Each functional module is designed to have four building blocks: µcontroller, functional component, communication and power supply as shown in Fig 1. AVR and C51 family controllers are used for the µcontroller part. Functional part is designed as per the system requirements. Interface of these modules to main controller card is through dedicated TTL UART communication lines i.e. Rx (Receive), Tx (Transmit) and Ground. An optional RS232 line driver is also kept on each module for stand-alone operation.

HARDWARE MODULES

The newly designed instrument has a main controller card communicating with other functional modules and PC for controlling diagnostic devices. The description of developed hardware cards/modules are as follows:

Controller Card

The main controller card is designed using a Cavium ARM9 CPU based SBC (Single Board Computer) running on 250 MHz. This board has features like 64MB RAM, a bootable 4MB on-board flash, a microSD card slot and 5000 LUT (Look up table) Lattice FPGA. Interface to external devices can be done via Ethernet, USB host, USB device, or I2C ports as well as DIO, UARTs, and SPI which are implemented in the standard FPGA load. The SBC boots to Linux 2.6 from either an SD card or 4MB on-board flash having a bootable kernel image and an initial ram-disk image (Fig 2).

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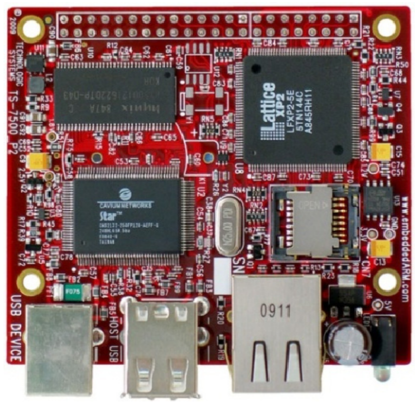

Figure 2: ARM-9 based Single Board Computer.

Stepper Motor Module

This card is designed to drive single high torque, high current stepper motor using FET based driver (Fig 3). The basic function of this module is to control the movement towards a given direction (in full/ half step) and to read the status of position switches & motor.

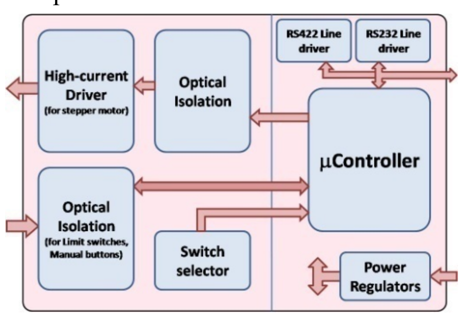

Figure 3: Block diagram of Stepper Motor module.

The module is designed to drive unipolar, bipolar and hybrid type of stepper motors. Optical isolation is provided between logic and driver part of the module to avoid unwanted glitches in communication lines.

X-Y Slit Module

The beam slits are used to control the beam aperture in the injection and extraction lines.

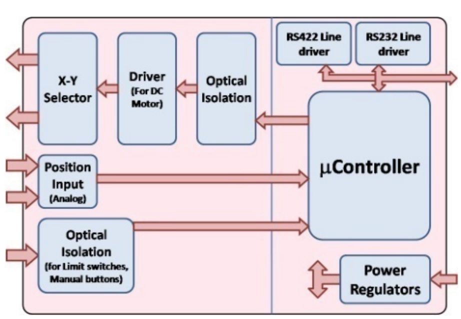

Figure 4: Block diagram of X-Y Slit module.

As the slits are installed in a pair {horizontal (X) and vertical (Y)} directions, the module is designed to control two slits as shown in Fig 4.

The movement of the slits is controlled by operating geared DC motors, one at a time, whereas position is read by potentiometric position encoder, fixed with the moving arms. Speed of the motors is controlled using built-in PWM in on-board controller. Positional switches are read during movement to restrict the motion beyond its limits.

Encoder Read-Out Module

All the major diagnostic components like three finger probe, viewer probe, magnetic channels etc. in SCC uses optical (Incremental & absolute) encoders, for position measurement. The encoder read-out module is designed interfaces with incremental type encoders to read 32-bit of absolute positional data (Fig 5).

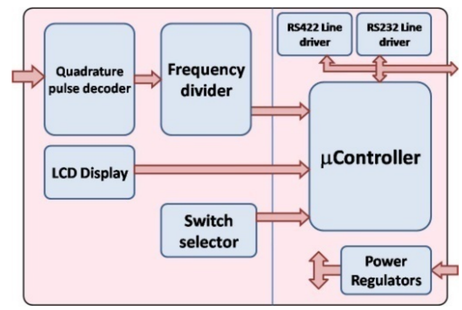

Figure 5: Block diagram of Encoder Read-out module.

A count with specific multiplication factor of decoded pulses from quadrature clock converter provided positional data. Other features like auto correction of position using index pulses and local/remote calibration are also introduced to avoid cumulative error in position. The position data is saved in local memory and calculated absolute position is displayed in an LCD panel.

Relay and I/O Module

The basic function of the relay module is to operate different electro-pneumatic valves. Electromagnetic relays are used as switches for actuating diagnostic components like Faraday cup, Beam viewer, Gate valve, Track valve etc.

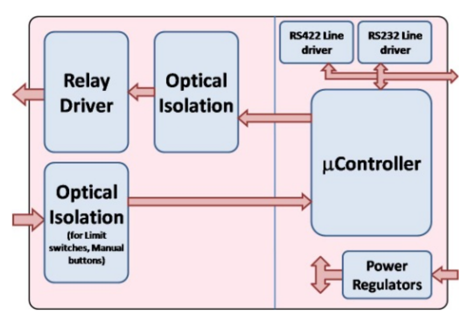

Figure 6: Circuit diagram of Input-Output module.

The I/O module comprises of relays operation with interlock inputs as shown in Fig 6. This card is useful for small beam diagnostic stations with a few components like combination of beam viewer & faraday cup in external beam line. Fig 7 shows example of an assembled module.

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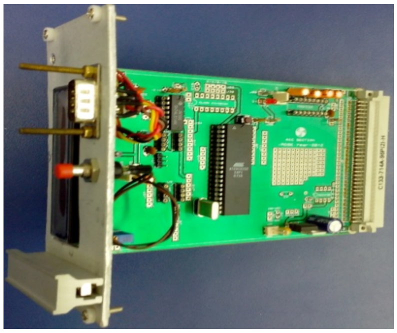

Figure 7: An assembled module.

CONTROL ARCHITECTURE

The control system for beam diagnostic in both the cyclotrons follows a 2-layer architecture. The operator interfaces (OPIs) are developed using MEDM (Motif Editor and Display Manager) which runs on standard Intel X-86 PCs. As per EPICS standard, OPIs interact with the IOC (Input-Output Controller) through control LAN following Channel Access (CA) protocol.

The main controller card, having ARM based Single Board Computer, runs the EPICS IOC. The IOC contains the required process variable list (database) for beam diagnostics purpose. The controller card communicates with functional modules through dedicated serial links. The device drivers for all theses hardware modules are written separately and included into the IOC.

CONCLUSION

Presently two sub systems are under operation with such newly designed instruments. The inflector positioning in the Superconducting Cyclotron is done with the combination of a linear and an azimuthal motion control. The external beam line diagnostic system in RTC is being upgraded from manual to automated controls using these new modules.

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