

HIGH VOLTAGE CONTROLLER SYSTEM FOR SPECTROSCOPY DIAGNOSTICS OF SST-1

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Abstract

We have developed special instrumentation for spectroscopy diagnostics of the SST-1 Tokamak. Light output in the visible spectrum is guided through fiber optics from the Tokamak ports to the diagnostics Hall, where photo multipliers tubes and other instrumentation electronics are kept. High Voltage (0 - 1500 V) bias generation electronics is required to bias these PMTs. Total 14 PMTs to be biased for overall requirements of the diagnostics. We have developed modular electronics for HV bias generation, which consist of one controller and seven HV modules. We have designed and developed FPGA based controller card which controls seven HV modules. The Slot-0 card is having Spartan 3E FPGA and Standalone Controller Area Networking (CAN) controller. 32-bit RISC processor Microblaze has been deployed into the FPGA. We have used Hitek make HV supply modules which is programmable. In the HV modules, Analog Device Inc. make iCoupler, digital isolators are used to break the ground loops and to avoid ground-lifting problem. Various features like Manual mode/Remote mode operation, HV ON/OFF, HV Value setting through remote GUI have been developed on LabVIEW software.

SPECTROSCOPY DIAGNOSTICS ON SST

Spectroscopic diagnostic is an important tool to know about impurity content in plasma and other plasma parameter like electron and ion temperature, electron density, Z-effective. Light from plasma is been transported from a glass window through optical fiber and lens arrangement up to the detector, (photo-multiplier tube). In order to detect a range of signal we need to keep options of variable gain and filter bandwidth, programmable biasing of PMT to detect weak signals. This helps to study some of the perturbation at faster time scale.

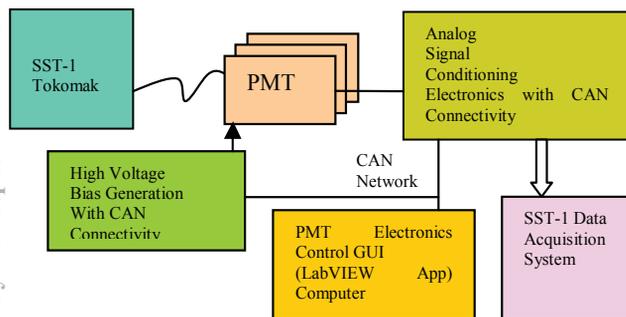


Figure: 1 Spectroscopy Diagnostics scheme of SST-1.

So we need to design electronics system with which we can play to study and monitor this phenomenon in plasma and characterize it during experimental campaigns. Total seven optical ports will be used for spectroscopy diagnostics of Phase-1 of SST-1 development. Figure 1 shows the diagnostics general block diagram.

HV ELECTRONICS DESIGN

The SST-1 spectroscopy diagnostics requires two types of electronics, one is analog signal conditioning, which is responsible for amplifying PMT current output and converting into voltage. The second one is high voltage bias generation. To meet the physic experimental requirements it was decided to keep the high voltage remotely programmable. To achieve the above mentioned goal modular electronics development was chosen. The 4U/10T size modular chassis is housing of the electronics pcbs. This chassis has total eight 4U slots, The Slot-0 is Microprocessor based card. Remaining seven slots (Slot-1 to Slot-7) are high voltage generation modules. The Slot-0 controller is intelligent device and is responsible for overall control of all seven HV modules and also communicates with remote computer with Controller Area Networking (CAN) protocol. We have chosen 32 bit RISC architecture based MicroBlaze soft processor on FPGA as main control unit. Because it is soft processor we could add many soft peripherals to it according to requirements of controlling seven HV modules.

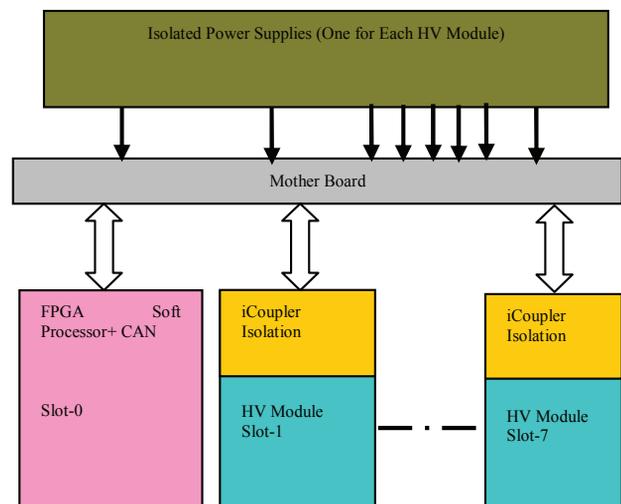


Figure: 2 Modular structure of HV Electronics.

At the time of designing electronics we also considered grounding issues, PMTs are connected to not only HV modules but also seven different transconductance

amplifier. These seven amplifiers use common reference ground and are housed in separate 10T/6U chassis. If we develop seven HV modules having common reference then it could lead to ground loop formation. Also because of safety we decided to provide isolation to HV modules from tokamak signal ground. To meet above two requirements we decided to generate floating HV i.e. each module should have its own reference point and there is no common reference for all seven modules. To achieve this we isolated all the digital control lines to and from microprocessor with Analog Devices Inc make iCoupler devices, iCoupler is digital isolator with chip scale transformer inside. This provides 5kV isolation to signal ground and also helped in breaking the ground loops. The secondary side of iCoupler is HV module interface, this HV module interface is powered with isolated AC/DC converter from MORNSUN power, China. Separate AC DC converter for each module is used for HV bias to generate floating supply for each module.

Slot-0 Controller Hardware

As mentioned above this is main control unit for the entire system. We have used MicroBlaze soft processor. The MicroBlaze Micro Controller System (MCS) is highly integrated standalone processor system intended for controller applications [1]. Data and program is stored in a local memory, debug is facilitated by the MicroBlaze Debug Module, MDM.

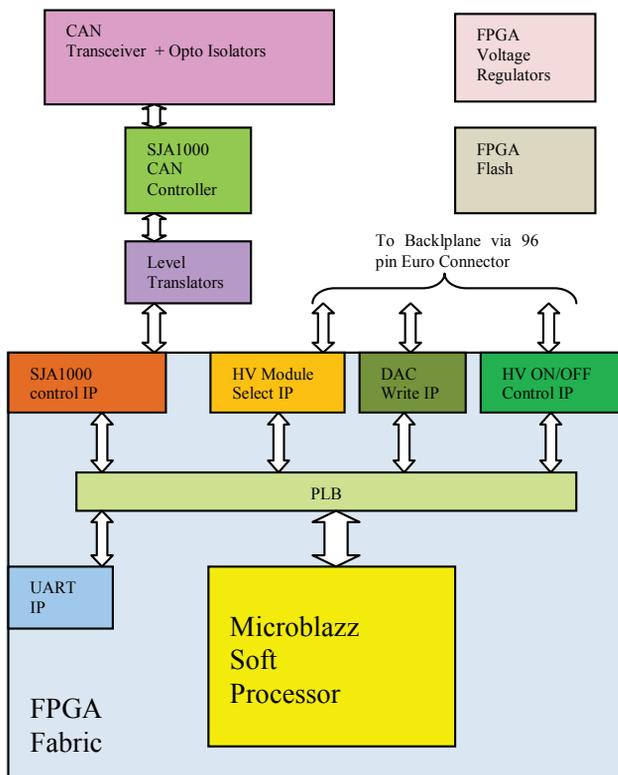


Figure: 3 Slot-0 Controller Blocks.

Xilinx Platform Studio (XPS) is used to configure and set up the hardware platform of the soft processor. We used external standalone CAN controller SJA1000 as CAN

peripheral IP was not available with us. We decided to use external hard block. The processor receives various commands and HV value, HV ON/OFF information from the GUI computer over CAN network. Upon receiving the CAN frames it decodes them and then performs actions of turning ON/OFF HV module or HV amplitude setting. To turn ON/OFF one module one bit Output port of GPIO IP is used. Total such 7 lines are used for turning ON/OFF HV modules. HV amplitude is set by 0 to 10V control voltage generated by Digital to Analog Converter inside the HV module. DAC update IP is developed for accessing the DAC inside the HV Modules via backplane from Slot-0.

High Voltage Module Hardware

The Hitek make HV supply modules are used inside the HV Module which needs 0-10V control voltage to set the HV output from 0 to 1500V. Each module receives isolated 24V supply from backplane via 96pin euro connector. Each module also received digital lines from Slot-0, which are HV ON/OFF, DAC Data lines (12bit), DAC Write strobe signal, Module identification 4 lines. The backplane is designed in such a way that each HV modules can be inserted in any slots from, Slot-1 through Slot-7 of the 4U chassis. DAC write strobe and HV ON/OFF signals are uniquely routed for each module in the backplane. The hardware also supports manual operation of the individual HV Module. DPDT switch is provided on facial plate of each HV Module to operate module either in Remote Mode or Manual Mode.

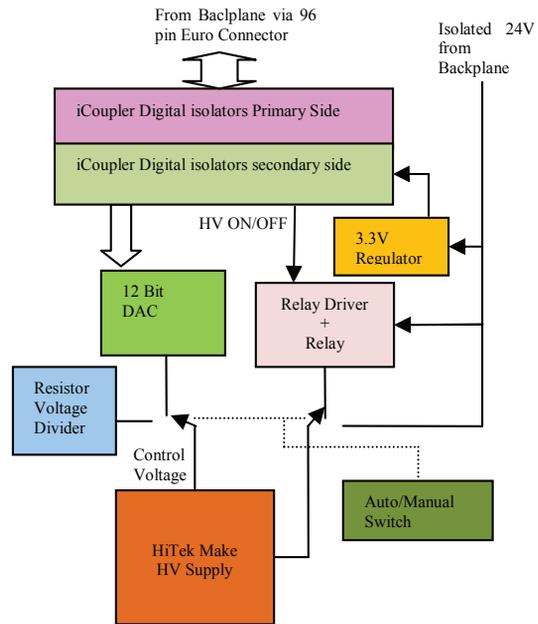


Figure:4 HV Module Block diagram.

In Manual Mode the Hitek power supply receives control voltage from voltage divider and its voltage is controlled by binary switch available on facial plate. In Remote mode the Hitek module receives control voltage from 12 bit Digital to Analog Converter. 12 bits provides enough resolution to vary the final HV output in step of 1V.

This DAC is controlled by the digital control signals from the Slot-0 Controller. We decided to route only digital signals over backplane of the chassis. Analog Signals suffer from noise because of long traces and two euro connectors in their signal path. This helped in achieving better accuracy and precision in HV setting.

SOFTWARE PART

Embedded Program for MicroBlaze

Xilinx Platform Studio (XPS) is used to develop the C code for MicroBlaze soft processor. XPS provides various APIs to interact with various IPs. It prepares various CAN frames and also decodes received CAN frames and executes subroutines of setting DAC value, HV ON/OFF bit setting. Total four such chassis will be used. We use CAN ID field of CAN frame to address the particular Chassis. We have introduced another fields like Code ID, Module ID, Code Data which are part of the CAN Data fields and used to address the particular module within chassis and performing various actions. Embedded software flowchart is shown in following Figure 5.

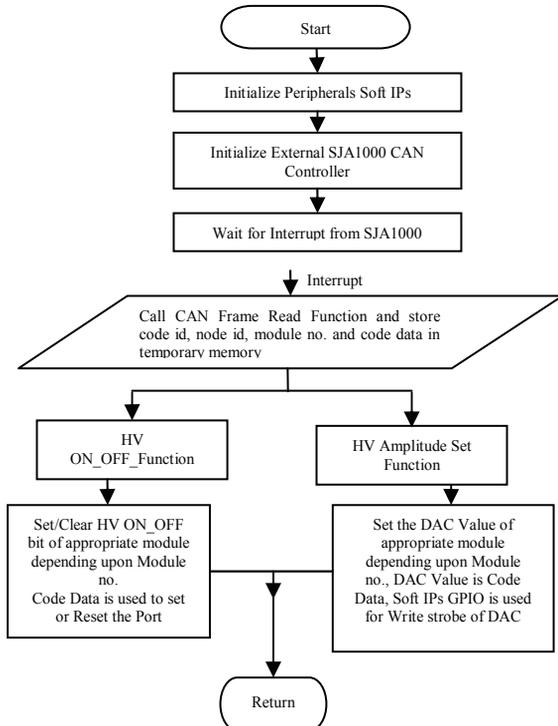


Figure: 5 Embedded Program Flowchart.

GUI using LabVIEW

To access the hardware remotely virtual instrumentation software LabVIEW is used to develop the Graphical User Interface. With this GUI and CAN connectivity the complete hardware system is visualized virtually on the computer screen. GUI is common interface for Analog Signal Conditioning hardware and HV Electronics. We have used National Instruments make USB-CAN Module NI8473 to connect CAN bus to computer through USB Port. This software also prepares log file for the HV setting and stores in remote computer. LabVIEW GUI is also interlocked with Master Control System (MCS) of SST-1. This GUI and MCS communicates with TCP/IP protocol and exchanges various plasma shot related information, like shot No., HV electronics READY status, Start of New Shot, End of Shot, Shot Abort Request/Grant. Figure 6 shows “Virtual Hardware”, i.e. LabVIEW GUI screenshot.

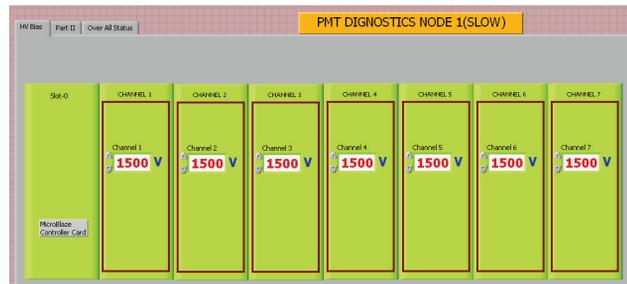


Figure: 6 Spectroscopy GUI (HV Chassis View).

RESULTS

Usage of digital control for setting and monitoring of High Voltage results in excellent accuracy and precision. We took measurement using Keithly make digital multimeter to read the high voltage output of HV Module. The variation between set voltage and actual measured voltage is less than 1.2V for entire range from 0 to 1500V. We also conducted experimental campaign of SST and tested this HV system with PMTs, Analog Signal Conditioning Electronics. We could get good results of whole spectroscopy System and the analog signals were acquired by Data Acquisition System of SST-1. PMTs were tested with external light source as well as for first Plasma Trial shot of SST-1.

REFERENCES

[1] www.xilinx.com