The DØ High Voltage System

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ABSTRACT

The DØ experiment at the Fermilab Tevatron Collider uses approximately 1000 independently controlled high voltage supplies in the detector. The VME-based front-end of the high voltage system employs Motorola 68020 processors running the pSOS operating system. Host processes, running on VAX/VMS computers, communicate to the front-end computers via a local area network. The DØ Control Data Acquisition package, CDAQ, handles all the communication between the host and the front-end. The front-end hardware and software is structured to ensure robustness and flexibility. The host software provides intelligent and intuitive high-level control and monitoring of the entire DØ high voltage system, which helps optimize the response of detector components.

I. OVERVIEW OF THE SYSTEM

The DØ [1] detector consists of several components which have distinct high voltage requirements. Within a detector component high voltage modules of differing characteristics are used. The design goal of the DØ high voltage system was to optimize the detector performance by meeting the individual and collective high voltage needs for the 1000 high voltage supplies. The operation of the detector also demands an uninterrupted and accurate supply of high voltage for long periods of time. Reliability is the most critical requirement for the system. The data taking conditions change frequently and requires the control and monitoring of the entire system with minimum effort. The high voltage system must be robust, flexible, intelligent and intuitive. The DØ high voltage system meets most of these requirements.

The high voltage system consists of front-end systems and host-level processes which communicate through the standard DØ control path [2]. An individual front-end is a VMEbus-based system with six Motorola 68020 microprocessors handling up to 192 high voltage supplies. DØ employs 7 functionally identical replications of this front-end unit. The host contains a set of processes on VAX/VMS which are part of the DØ control and monitoring system. The host processes use CDAQ services to communicate with front-end nodes which reside on token-ring.

In the following sections we will discuss the various components of the system and our experience with it.

II. HARDWARE

The DØ high voltage hardware consists of VMEbus-based high voltage modules [3], a crate controller, micro-processors that control the high voltage hardware and a token ring for communication with external systems.

A. High Voltage modules

A high voltage module consists of a control board and 8 independently controllable high voltage supplies. There are 7 types of supplies with differing resolutions and voltage and current limits. The resolution is determined by the range of the 15 bit ADC and the maximum voltage limit. A typical supply provides up to 5.5 kV at a current of 1 mA.

High voltage is generated by a pulse-width modulator and a Cockroft-Walton voltage multiplier (fig.1) The supplies deliver voltage linearly over a wide range. The accuracy of the delivered voltage is largely determined by the noise level of the high voltage components which are typically 0.05% of the full voltage. The supplies also exhibit long term stability when properly installed and maintained. For the 5.5 kV supply the long term voltage stability is better than 10 volts over 6 months.

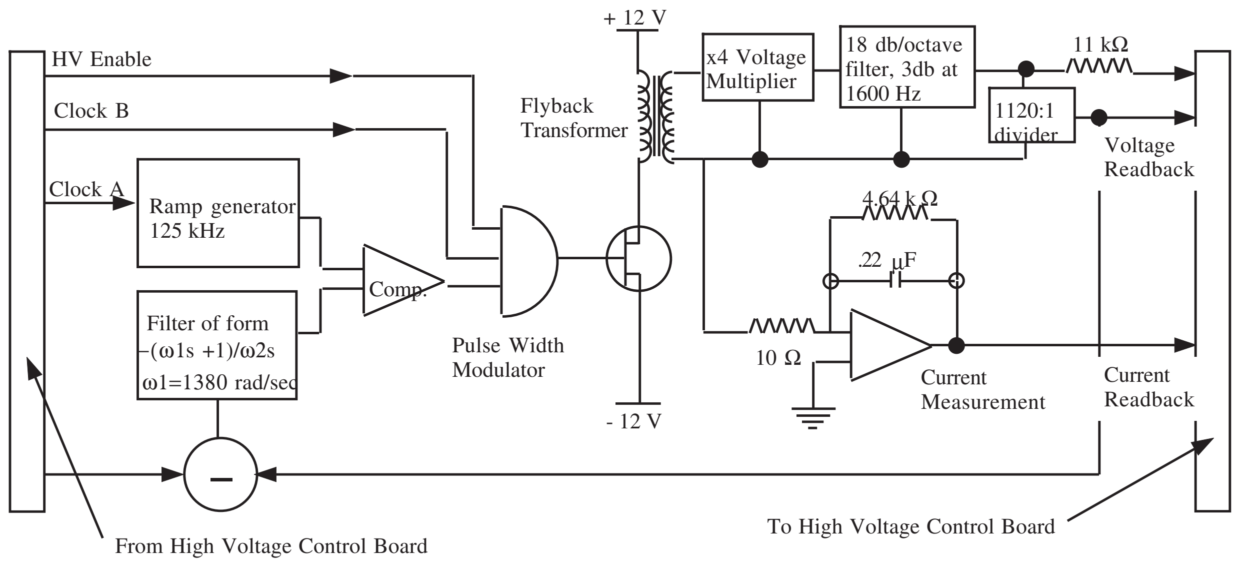

Fig.1 Block diagram of a high voltage supply

B. Front-end System

The front-end system consists of a crate controller which handles the communication between the host and the high voltage controller. The crate controller polls at 15 Hz to detect and report significant events. Signifcant events include high voltage trips, temperature alarm and inadequate low voltage supplies for the system. The crate controller communicates with the master process via command/ready queues.

III. SOFTWARE

A. Front-end Process

A front-end node consists of one master and multiple subordinate processes. The master process coordinates the activities of up to 4 subordinate processes. Each subordinate process handles up to 48 high voltage supplies. The subordinate process directly controls the high voltage hardware through memory I/O. The master and subordinate processes execute the user command within well defined states as seen in the state transition diagrams shown in fig.2.

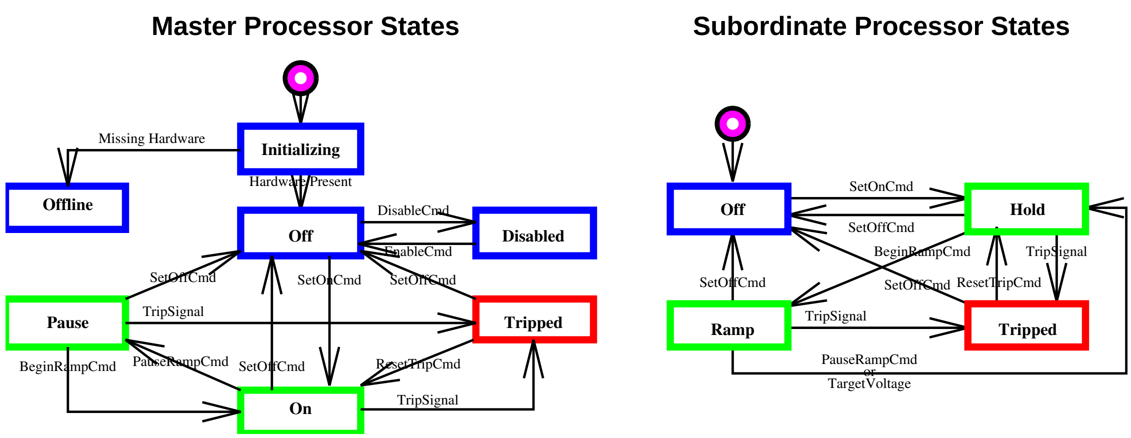

Fig.2 State Transition Diagram

The front-end maintains a set of circular buffers which are used for monitoring and diagnostic purposes. A command status buffer records up to 256 of the most recent control commands and their execution status. The master process records the time-averaged voltage, current, and standard deviation of current at 5 minute intervals in a slow history buffer which can hold 400 events. The subordinate process maintains a fast history buffer at approximately 25 Hz which can hold 1500 events.

B. Host Process

The host consists of 3 processes: the control process, the global high voltage client and the system high voltage monitor (HVMON). The system level Data Flow Diagram of the host control processes is shown in fig.3.

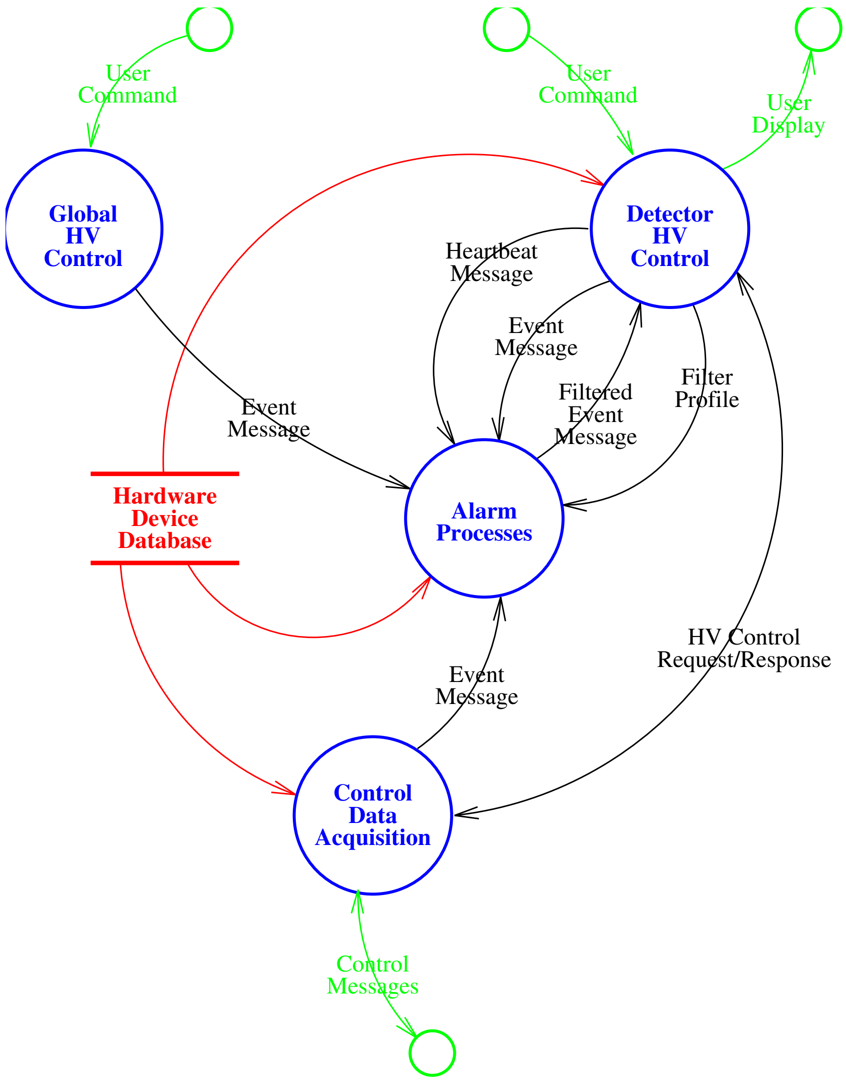

Fig.3 Data Flow Diagram

The host control process sends commands to the front-end and reads back data periodically. It receives high-voltage command scripts from a user-defined or process-defined menu system. The script and parameter files are used to control the high voltage in an intuitive manner. The user can also control the high voltage using a keyboard and in that case the control process also provides a simple editor. Although a single process can control the entire DØ detector, we assigned one process for each major detector component. Presently, there are 11 high voltage processes running simultaneously. The control processes are also servers to the global high voltage client process. The control process periodically sends out a heartbeat signal to the central alarm server to report its state.

The global high voltage client process broadcasts, via the DØ alarm processor, the high voltage commands *full-voltage*, *stand-by,* or *reset_trip*. The control process then executes the corresponding script files, whose contents vary for each detector component. The global command can be ignored by the control processes when explicitly requested by a user. The global command is also announced using DECTalk.

The system high voltage monitor periodically reads high voltage data to determine the status of each supply. The status is represented using color block characters. The high voltage status of the entire DØ and a brief summary are shown in the display (fig.4). The arrangement of the high voltage channels closely resembles their physical arrangement. The status condition for each channel is defined by algebraic and logical relations. The definition is compiled to an interpretive form which is executed at run time. The definitions can also be inherited from another channel. All status changes are recorded in a database. The system high voltage monitor offers many tools that can be used in conjunction with regular periodic activities, but in practice user commands are rare.

The user interface to all the host processes was designed using the VAX Screen Management facility(SMG). It was originally designed to work in environments which did not have X display capabilities.

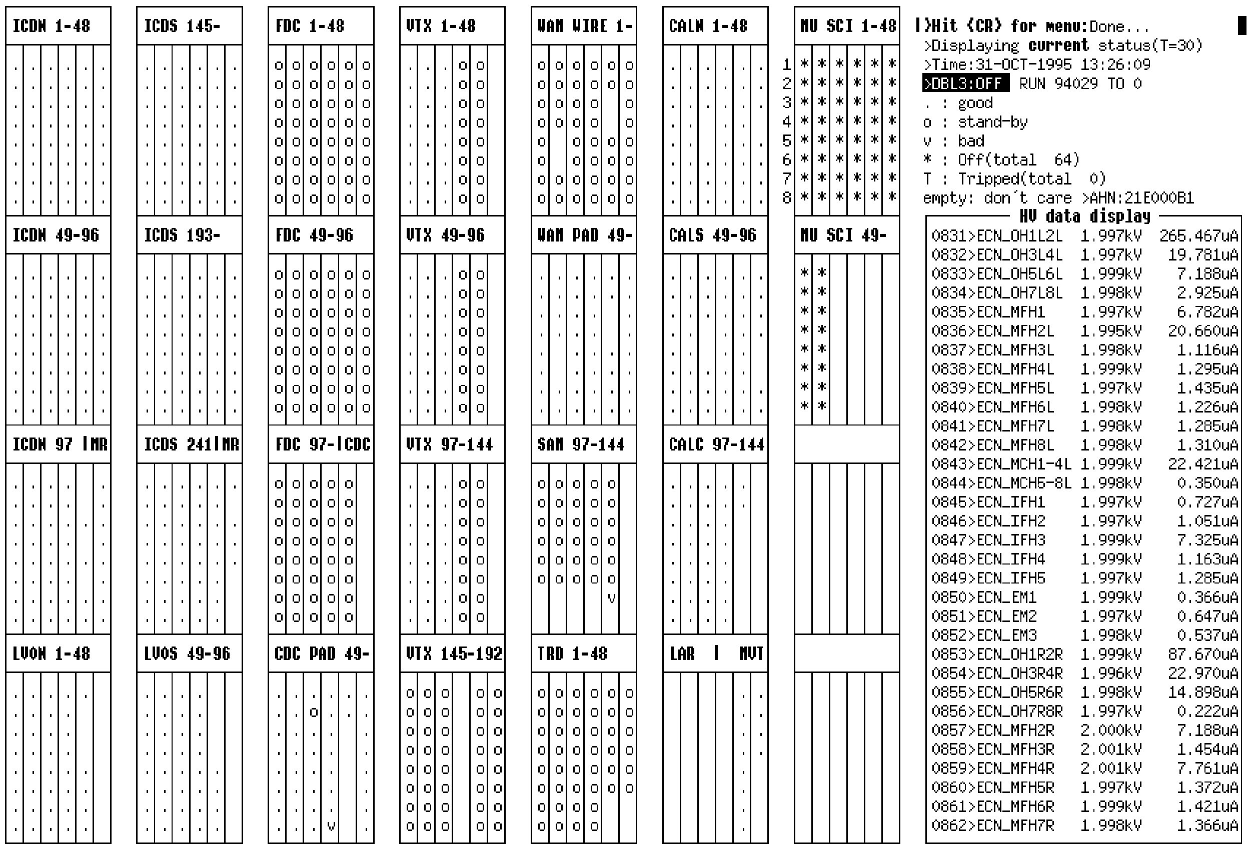

Fig.4 HVMON display

C. Diagnostics Support Package

A number of diagnotics tools were created for the high voltage system. The command queue buffer was used to debug command execution problems. About 1.5 days of slow history data is kept on the front-end to study the long term high voltage behavior of the detector. The fast history is used to debug both the detector and the high voltage system. The history data is accessible from the control process, the system high voltage monitor and other stand-alone processes. The history data is stored in Ntuple files, which can be viewed using PAW.

IV. EXPERIENCES AND LESSONS

Initially, DØ developed PC applications for controlling the high voltage. The PC environment was particularly useful during the hardware development phase and is now occasionally used when there are network disruptions which prevent the use of the operational system. It can also calibrate high voltage electronics and has an extensive help facility. However, because it was rarely used during the running of the experiment, casual users did not remember the command sequences and felt uncomfortable with it. We think an identical user interface for both the PC and host system would have avoided this problem.

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