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A VACUUM CONTROL SUBSYSTEM FOR THE FERMILAB TEVATRON

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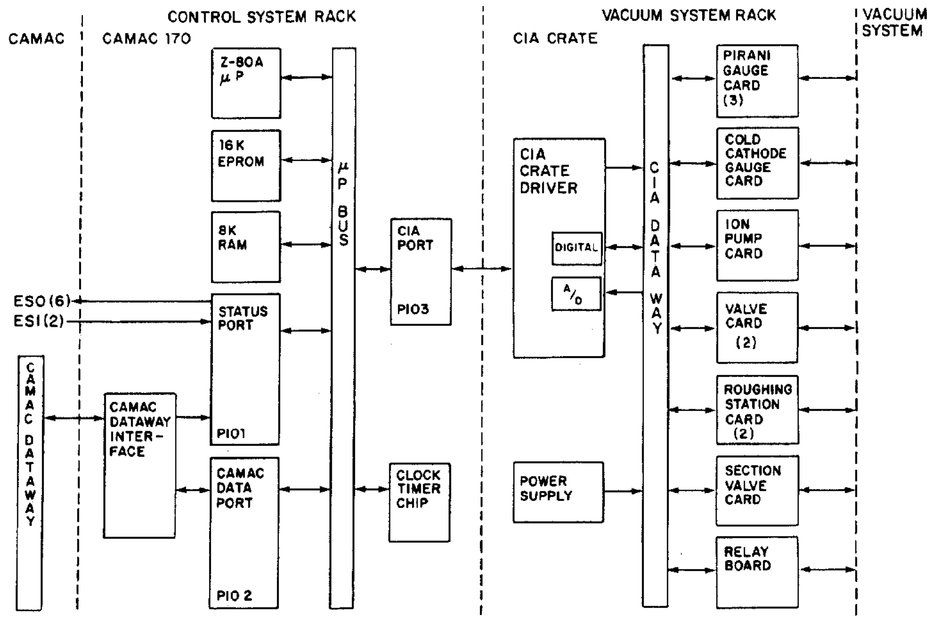

Figure 1. Vacuum Control Subsystem Block Diagram

Introduction

The Tevatron Vacuum System is controlled using a series of general purpose, CAMAC resident microprocessor modules and multiplexing crates remote from the CAMAC environment.

The system described is resident at each of twenty-four service buildings that house electronics support for the accelerator. These 24 sections are similar in numbers and types of devices in the system and are therefore supported by identical hardware and software. Each section in effect comprises two independent vacuum systems, the insulating and the bore tube vacuum. The insulating vacuum is monitored by a combination of Pirani and Cold Cathode gauges. Mechanical pumping for the insulating vacuum is provided by two roughing stations each consisting of a turbomolecular and a rotary vane pump, two electropneumatic valves to allow independent or simultaneous pumping of the related half cells, and an additional Pirani gauge to monitor roughing pressure. Bore tube vacuum is monitored by Pirani gauges, cold cathode gauges, and ionization gauges for ultra-high vacuum measurement. Rough pumping of the bore tube is accomplished via portable manually operated pump carts which are not monitored by the control system. Two additional bore tube section valves are monitored and operated by the control system at each service building.

Vacuum controls at each of the six long straight sections of the accelerator exhibit unique configurations and are supported using a subset of the hardware and software described.

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The vacuum subsystem is designed to operate independently, requiring minimal interaction with master computers (host and resident local intelligence)[1] under normal conditions. The system is also intended to reduce the host's computational burden.

CAMAC 170 Module Hardware

The CAMAC 170 (CIA controller) module is a general purpose intelligent module that consists of the circuitry required to communicate through the CAMAC environment with the master computers, a Zilog Z-80A microprocessor, and peripheral interface to control the external multiplexing system.

The processor communicates through three Z-80A Parallel Input/Output (PIO) devices configured as: 1) Status Port, 2) CAMAC Data Port, and 3) Peripheral Control Port. It is additionally supported with one 4 channel Z-80A Clock Timer Chip (CTC), up to 16K bytes of program memory using 2716 EPROM's, and up to 8K bytes of random access memory using 4118 static RAM's. The system is driven with a 4 MHz crystal clock driver.

The CAMAC interface includes function decoding, a pair of twenty-four bit wide registers for read data and write data, twelve bits of software generated status, six of which also raise a Look At Me (LAM) condition (used restrictively as an alarm condition), and six bits of hardware status, one of which is the micro processor heartbeat bit that raises a LAM condition in the failed state.

The 170 module receives up to 2 external status inputs and provides up to 6 external status outputs to other systems using one of the I/O connectors on the double wide module. The second I/O connector is used

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as the CIA port. Eight-bit bytes of parallel address are provided to the Control's Interface Adapter (CIA) crate for control/data transfer and additionally eight-bit parallel data bytes are returned from the CIA crate in response to commands from the processor.

CIA Crate

The CIA crate provides a convenient housing for all electronics involved in the multiplexing and conversion functions of the system. Sixteen 3/4" wide slots are provided for use as digital and/or analog multiplexers along with support electronics for the particular system. In addition to the sixteen useable slots, a plug-in power supply and CIA Crate Driver occupy two slots in the crate.

The crate dataway provides eight data lines, two control function lines, four subaddress lines, a multiplexed analog line, power supply bussing, and individual module select lines to each of the sixteen available slots from the crate driver.

The plug-in modules are 9" x 10" and are provided with a 60 contact dataway connector for control and power bussing, and a 44 contact I/O connector for device interconnection. A back panel is provided as a convenient bulkhead for multiconductor cable transitions to external devices as required for a given system.

CIA Crate Driver

The CIA Crate Driver is accessed from the CAMAC 170 through a single 40-conductor ribbon cable up to 7m long. The driver contains the decoding, timing, and driving circuitry to access each of the sixteen slots in the crate. Address decoding is provided to allow up to two crates to be daisy chained using the 4 subaddress bit mode, or four crates using the 3 subaddress bit mode. These modes as well as the crate address are switch selectable on the crate driver.

A ten bit A/D converter is provided with input buffering to allow a 0V to +10.23 V full scale signal. Jumpers are provided to convert to ± 5.12V full scale offset binary or 2's complement results.

Dataway cycles in the CIA crate are initiated upon receipt of the appropriate command from the CAMAC 170 module. For a digital read of a single byte of data or an analog-to-digital conversion of a single channel on any of the CIA modules, two control bytes must be received in the proper order with the proper crate address to set the function and module address. Upon receipt of the second control byte, the crate driver initiates a dataway cycle. In the case of a digital read, incoming data is driven via the output port to the 170 upon receipt of the selected module acknowledge. In the case of an analog-to-digital conversion, the dataway cycle is begun and a 100 μsec delay is set to allow settling time of the high impedance multiplexed lines. Following this delay, the 25 μsec conversion is initiated. Two data bytes are then returned to the 170; the first contains the eight most significant bits, the second contains the two least significant bits of the result, left justified. If the acknowledge is not received from a selected module, a Peripheral Fail bit is raised to the 170 to indicate a problem. The crate driver must then be reset by the 170 to continue operation.

To initiate a digital write of an eight bit word to a module, the appropriate two control bytes are followed directly by the word to be written to the selected module. The dataway cycle is then initiated and terminated upon receipt of the acknowledge indicating the data has been latched by the receiving module.

Using the 3 subaddress bit mode, up to eight channels of analog, eight bytes of digital read, and eight bytes of digital write data may be multiplexed on each plug-in module. Using the 4 subaddress bit mode, sixteen channels of analog, sixteen bytes of digital read, and sixteen bytes of digital write data may be multiplexed. However, in the 4 subaddress bit mode, only two crates may be daisy chained to a single 170 module. These capabilities are limited only by the physical card size and 44 contact I/O connector.

CIA Vacuum Modules

To support and control the vacuum system, seven types of special purpose cards are installed in the CIA crate. Pirani gauge cards contain six sets of gauge controller circuitry providing an analog channel, one fault status bit, and one permit bit each. All six status bits are read as a single byte and likewise all six permits via two digital reads of the card. Each analog channel is read independently. Additionally, two calibration channels are provided, one at 10 VDC and one at ground.

Cold cathode gauge cards contain only the multiplexing circuitry for 16 analog inputs from the separate cold cathode chassis. Ion pump cards contain multiplexing for 6 ion pumps, two calibration channels as on the Pirani cards, plus control for on/off and error reset functions.

Valve cards each interface two valves with one byte of open/close control, and two bytes of status for open/closed, differential pressure, and request to open status. Roughing station cards provide a single control byte to turn the pumps on/off as well as control of the two valves associated with the station. Two bytes of status are returned, one for valve status and the second for pump status.

Section valves are handled using a variation of the two valve card, and a relay board is provided for higher voltage switching. The vacuum modules are described in detail in a related paper.[2]

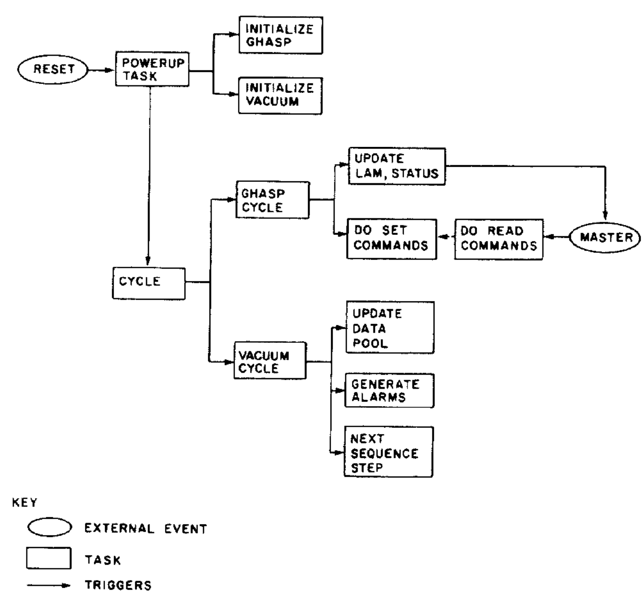

Figure 2. Vacuum Subsystem Software Task Structure

CAMAC 170 Module Software

The software is designed around a large data pool which contains several types of data. On the highest level are summary statistics: average, minimum, and maximum house values for bore tube and insulating vacuum expressed as floating point values in Torr, and mode indicators: normal, pumpdown, etc. On the next level are individual gauge readings in Torr and volts, status bits for the various types of vacuum devices, and error data including individual error bits, and additional information for certain types of errors. A standard byte string test pattern is included for debugging. At the lowest level are CIA addresses and a memory dump feature.

The software itself comprises three modules. The first, called the "system core," is common to other Tevatron subsystems. It initializes and cycles the other two software modules and detects and handles basic system errors: a failed stack test, illegal memory access, illegal port access, and unexpected interrupts.

The second software module, General Host And Subsystem Protocol (GHASP), handles all communications with master computers and is common to all intelligent subsystems. The GHASP module keeps the LAM bits up to date and processes two types of commands: reads and sets. Read commands are handled immediately by accessing the data pool. Set commands are not done immediately; instead, they are buffered and deferred until a "safe" time in the system cycle when they are processed by routines which update the data pool, change modes (e.g. begin pumpdown), or control devices (e.g. open a valve). Commands which the software considers dangerous are rejected unless the master overrides the rejection.

GHASP also provides a useful debugging mode, "regurgitation," for testing communications integrity. In this mode, bytes are merely returned either complemented or in original form depending on the CAMAC function code used.

The third module contains the vacuum control software. It cycles through the following three tasks:

1. The data pool is updated by interrogating the CIA hardware (while noting any problems) and the external status (which provides a bit of information from the refrigeration subsystem), and by generating the higher level data from these raw readings.

2. Errors (simple out-of-bounds as well as more complex conditions) are detected, recorded in the data pool, handled if possible, and reported to other systems (master computer, refrigeration subsystem, beam abort subsystem) if necessary.

3. Sequences (such as pumpdown) in progress are checked and new steps taken if the time is appropriate.

Summary

The CAMAC 170 module and CIA crate provide a convenient, cost effective method of interfacing any system requiring a large number of simple devices to be multiplexed into the Accelerator Control System. This system is ideal for relatively slowly changing systems where ten bit analog to digital conversions are sufficiently accurate. Together with vacuum interface CIA cards and prom-based software resident in the 170, this system is used to provide intelligent local monitoring and control for the Tevatron vacuum subsystems. Although not implemented in the vacuum interface, digital to analog converters could be included on the plug in modules as well, providing a total digital and analog multiplexing scheme.

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