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Standard Design for National Ignition Facility X-Ray Streak and Framing Cameras

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The x-ray streak camera and x-ray framing camera for the National Ignition Facility were redesigned to improve EMP hardening, protect high voltage circuits from pressure transients, and maximize the use of common parts and operational software. Both instruments use the same PC104 based controller, interface, power supply, CCD camera, protective hermetically sealed housing and mechanical interfaces. Communication is over fiber optics with identical facility hardware for both instruments. Each has three triggers that can be either fiber optic or coax. High voltage protection consists of a vacuum sensor to enable the high voltage and pulsed microchannel plate phosphor voltage. In the streak camera the high voltage is removed after the sweep. Both rely on the hardened aluminum box and a custom power supply to reduce EMP/EMI getting into the electronics. In addition, the streak camera has an EMP/EMI shield enclosing the front of the streak tube.

I. Introduction

The National Ignition Facility (NIF) is a 192 beam frequency tripled (λ=0.35μm) Nd:glass laser system designed to deliver an on target energy of 1.8 MJ in a 21 ns pulse[1]. Diagnostics are inserted into the chamber using Diagnostic Instrument Manipulators (DIM) located along the equator and top of the target chamber. A standard DIM instrument interface and airbox to protect the electronics was developed and implemented for x-ray streak cameras[2] and framing cameras[3]. Both types of cameras provide spatial and time resolved images using x-ray pinhole snouts. The x-ray streak cameras provide one dimensional imaging with a temporal window of 1 to 100 ns. The framing cameras provide two dimensional imaging on one, two or four microstrips that can be timed up to 50 ns apart.

The initial standard defined the cables and connectors for: (1) power, (2) electrical triggers, (3) optical triggers, (4) electrical monitors, (5) optical monitors, (5) fiber optic communication, (6) cooling lines. The standard also included trigger specifications. The electrical trigger specifications were rise time, pulse height and width. The optical trigger specifications were wavelength, optical power on/off, rise time pulse width and maximum duty cycle.

Different organizations designed and built diagnostics which resulted in different power supplies, onboard computers, internal environmental monitors and CCD cameras. This variation complicated software development and the maintenance of the diagnostics. Based on experience using these cameras the standardization was expanded to include the following items in the airbox: (1) power supply, (2) CCD camera (3) PC104 stack and (4) the high voltage is gated or crowbarred to protect the electronics.

The framing camera (GXD: Gated X-ray Detector) was upgraded to the new standard. A new x-ray streak camera (DISC: DIM Imaging Streak Camera) was designed to the new standard.

II. DESCRIPTION OF STANDARD ASSEMBLIES

The modules for a diagnostic as shown in figure 1 are; (1) airbox, (2) power supply, (3) PC104 computer, (4) CCD camera, (5) diagnostic module. A block diagram is shown in figure 2. In addition there is a 100 inch long set of cables to connect the diagnostic to the DIM cable track.

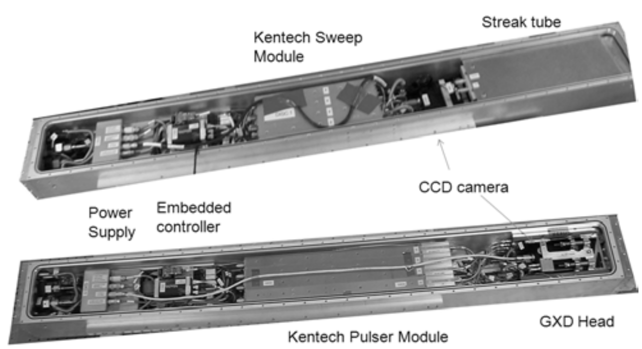

FIG 1. Major modules in a standard x-ray steak camera and x-ray framing camera. Right side is toward the target.

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The 100 inch cable bundle consists of a metal sheathed set of optic fibers, two power cables, one coax cable, two water lines and one airline. The power cables connects to “interlocked” and “non-interlocked” power supplies. The 6.25/125 (core/cladding diameter in microns) multimode fiber optic cables are: (1) optical fiber for main trigger, (2) optical fiber for aux trigger, (3) optical fiber for CCD trigger, (4) two fibers to communicate to the CCD camera, (5) two fibers to communicate with the framing camera or sweep camera controller.

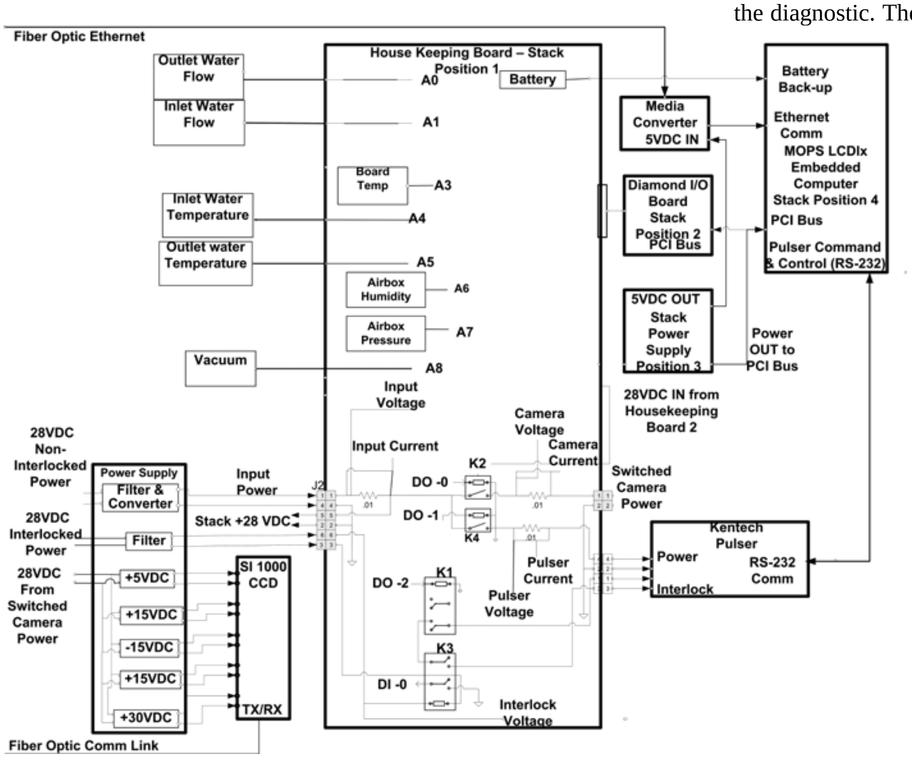

FIG 2. Block diagram of standard modules in both the GXD and DISC

The airbox containing the diagnostics at a pressure of one atmosphere of air or nitrogen is 56 x 6.25 x 6.125 inches and 0.625 inches thick. The box is aluminum to minimize weight and neutron activation. A cooling plate is attached inside the box. For EMP protection the airbox is designed as a Faraday shield for the electronics inside the box. The outside of the box is grounded through the DIM to the Target Chamber and building ground. All electrical cables have EMI connectors with shields connected to the airbox. The internal electronics power ground is at the diagnostic rack in the NIF mezzanine. The mezzanine is outside the NIF target bay radiation shield wall and contains the computers, power supplies and recording systems for the DIM based diagnostics.

Unlike the Spectral Instruments 800 camera used in previous diagnostics the Series 1000 has a sealed head[4]. This eliminates the problem of condensation forming on the bond wires and damaging the CCD. The CCD is a Kodak 16801E (4096 by 4096 by 9 micron square pixels) attached to an Incom 33mm long fiber bundle with 6 micron fibers. Communication is over a fiber link to a Spectral Instruments PCI control board installed in an Instrument Based Controller located in the diagnostic mezzanine. An optical trigger is used to prevent electromagnetic interference from getting into the diagnostic.

The power supply in the airbox is shown in figure 3. Two Agilent 6653A power supplies are located in the diagnostic mezzanine can provide 35 VDC at up to 15 Amps. The standard voltage at the DIM interface is 28 VDC. One power supply called the “non-interlocked” power supply supplies 28 VDC to operate the PC104, the CCD camera, and low voltage section of the diagnostic. The other power supply is interlocked to the DIM vacuum. It can only turn on when the vacuum pressure in the DIM is below 5x10^{-5} Torr. This prevents damage to the high voltage section of the diagnostics due to air breakdown at high voltage. The power cable shield is tied to the airbox.

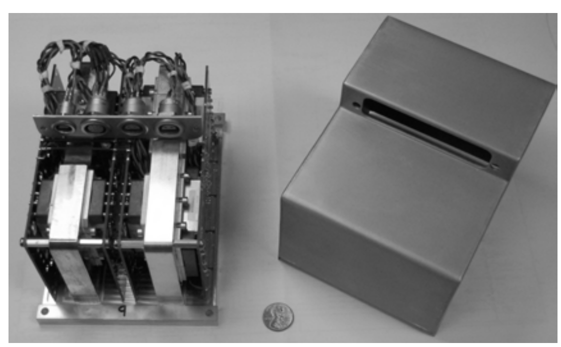

FIG 3. Power supply showing the bottom cooling plate and the two internal heat sinks with DC:DC converter modules mounted on both sides

Inside the airbox both the “non-interlocked” and “interlocked” power goes to VICOR MFIAM5B filter input and attenuator modules. The module provides class B EMI filtering. In addition it has transient immunity of 200 volts for 1 μsec duration and 250 volts for 1 to 100 nsec burst. Both 28 volt supplies go to the PC104 house keeping in order to measure the voltage and current. The "non-interlocked" power then goes back to the power supply and DC:DC converters and provides the operating voltages for the CCD camera.

The primary controller is based on PC104+ architecture with a form factor shown in figure 4. The controller provides communication for the Kentech pulser[5], monitors the voltages, and airbox environment, and allows the user to separately control the power to the Kentech pulser and Spectral Instruments 1000 camera. The stack consists of a processor board, analog/digital input/output board, a housekeeping board and a power supply board.

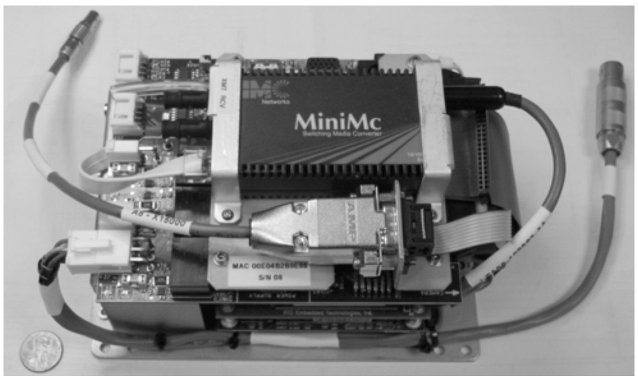

FIG 4. Internal computer based on PC104+ architecture.

A primary factor in the selection of Krontron MOPSlcdLX microprocessor board is the 1 GByte of memory. This is critical because when the diagnostic is remote booted over the Ethernet using the LAN boot, NIF software downloads the Microsoft Windows XP operating system. The diagnostic is thus run utilizing the Windows XP operating system. One RS232 port is used to communicate with the Kentech pulser. The electrical onboard Ethernet port is connected converted to fiber optic by a MiniMc TP-TX/FX-MM1300-ST media converter.

In order to prevent damage due to overheating or moisture sensors monitor: (1) water flow and temperature in and out of the airbox, (2) airbox air pressure and humidity, and (3) board temperature. The pressure outside the airbox is monitored to prevent enabling the high voltage until the pressure is below $5x10^{-5}$ Torr. In order to help identify a failing CCD or pulser the "non-interlocked" power supply voltage and current are monitored after the VICOR EMI filter, just before the CCD camera DC:DC converters, and going to the Kentech pulser. The "interlocked" power supply voltage is also monitored The housekeeping board connects to all the sensors and provides signal conditioning before the signal goes to the Diamond System MM-16-AT analog digital input/output board.

The digital outputs of the Diamond board control relays K2 and K4 on the housekeeping board that switch the power to the SI 1000 CCD camera and to the Kentech pulser. Another digital output controls relay K1 that combined with relay K3 enables the high voltage permissive to the Kentech pulser. A digital input monitors the status of relay K3 which is controlled by the DIM "interlocked" power supply as shown in Fig 2.

The final stack board is the RTD Embedded Technologies HPWR104plusHR embedded power supply board. This 83 watt unit converts the 28 volts into the voltages required by the PC104+ bus.

The Kentech modules designed the streak and framing cameras have the following items in common: (1) operate on 28VDC, (2) integrate RS232 communications, (3) incorporate a contact closure interface to interlock high voltages generated by the modules, (4) provide interface with electrical and optical main and aux trigger interfaces, (5) provide electrical monitor signals for external recording of fast pulses, and (6) fast crowbar of the high voltage once trigger. The connectors for these core functions are the same on both modules. The modules also have the capability of measuring supplied voltage and current, temperatures and voltages and currents specific to the framing camera or streak camera operation.

II. CONCLUSION

The original interface standard was expanded beyond the basic airbox and cable interface to include the power supply, computer, CCD camera, and environmental monitoring. This allows some software modules to be the same for different diagnostic and reduces overall software development time. In addition the use of common modules allows for quick replacement of a broken module from inventory and reinstallation of the diagnostic while the failed module is being repaired.

III. ACKNOWLEDGMENTS

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[5] Kentech Instruments, Ltd. (Isis Building, Howbery Park, Wallingford, Oxfordshire, OX10 8BA.U.K.) Kentech manufactured DISC streak tubes and DISC electronic packages and GXD electronic packages. www.Kentech.co.uk

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