A High Voltage Distribution System for Mu2e Electron Tracker

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Abstract

This poster describes the design, development, and testing of a custom based High Voltage Distribution System (HVDS) and features an embedded Smart Switch (SS) which distributes high voltage (HV) from a one HV supply to 6 independent HV channels by using 1 to 6 Demultiplexer High voltage Mother Board (DHVMB). SS also used second 12 channels independent High Voltage Mother Board (HVMB) to operate straw-detector panels of straw-tube detector array in the Mu2e electron tracker. The HVDS also works as a independent single channel power supply by using a DC-DC converter. It controls for each panel and has independent ON-OFF, HV limits, current limits, filtration, channel isolation, and a Crowbar for over-current protection.

Introduction

The Mu2e experiment is a search for Charged-Lepton Favor Violation (CLFV) in a neutrino-less Muon-to-Electron conversion (Mu2e) in the field of a nucleus. If a direct Mu2e conversion occurs without neutrino emission, a mono-energetic, 105 MeV electron is emitted. This electron can be detected with a single event sensitivity of 2×10^{-17}, by tracking it's spiraling motion in a 4m long, high-resolution solenoid (RMS $\leq$ 200 keV/c) [1].

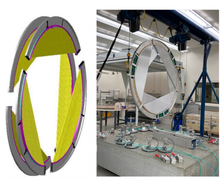

Figure 1. Six Panels are joined to make a Plane.] Two planes are joined back-to-back after a 60° rotation to form a station.(see the description in the text)

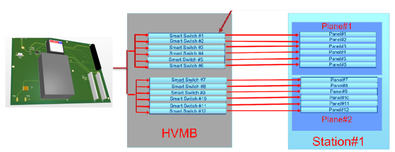

Figure 2. Mu2e High Voltage Architecture

A highlighted block summary of HVDS Instruments

- **The** Electron Tracker (ETD) consists of eighteen stations with each station containing 2 detector planes, a plane has 3 panels, and each panel contains 96 straw detectors. This gives a total of 576 (96x3x2) Straw Detectors (ST) per station.
- **Each** plane has independent HV input, control, filtration, and crowbar systems.
- **The** high voltage power supplies have active, over-voltage protection for each plane.
- **A** ground reference for the HV-power return is established at the panel by a connection to station ground.
- **There** is a HV supply and return cable for each panel.
- **Power** connections to the inside of the solenoid are made through electrically isolated vacuum penetrations.
- **Ground** loops are eliminated by using isolated power supply outputs.
- **Safety** ground is provided by station ground connections.
- **To** minimize delay and provide a fast crowbar trip, the SS is placed near the stations.
- **A** straw drift-field voltage of 1.45 to 1.5 kV, with a maximum supplied current of 250 μA max is provided.
- **The** accuracy of the HV voltage is approximately 0.1 V
- **The** current readout is better than 10 nA at 250 μA max.
- **The** HV is routed through the SS where a current MOSFET is used to remove stored energy in the HV distribution system within 2.5 msec avoiding repeated sparking.

Mu2e High Voltage System

1. **High Voltage Mother Board (HVMB)**, The HVMB contains 12 smart switch and an ardiuno controller. Each panel has independent HV input, filtration, and crowbar systems.
2. **Smart Switch Board**. In addition to the HV distribution, the Smart Switch (SS) also, monitors current and voltage of each panel. The voltage monitor uses a (1000 to 1) voltage divider, and a current monitor uses a shunt and an isolation amplifier. All SS boards are instrumented to provide individual ON-OFF and have HV/LV, isolation up to 2kV, filtration, and crowbar circuitry.
3. **Filtration circuit** To avoid noise in the long HV cables, there is a low pass filter for the HV input into the SS. This controls unavoidable spikes in the HV and reduces ripple-adding in the HV system.

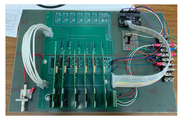

Figure 3. Test setup of Mu2e De-Multiplexer High Voltage Mother Board containing 6 SS with arduino module.

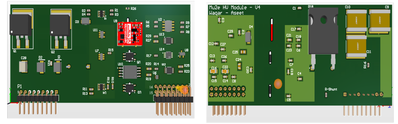

Figure 4. The Smart Switch with crowbar and filtration circuit.

HV Test and Validation

The system was tested for 600 μA to simulate a resistive load equal to 6 panels. The test observed the response when switching the HV on and off to simulates a pulsed beam by using the Arduino controller.

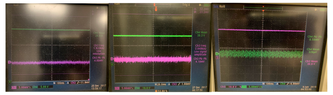

Figure 5. Ripple measured without switching the input power supply the test was applied to 3 different power supplies (left to right) without switching. 1.Wiener 4.60 mV(pp), 2.Bellinix 4.10 mV(pp), 3.Droege 8.50 mV(pp).

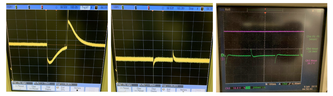

Figure 6. Sag/transition measured with switching (ON-OFF) input supply for the three power supplies (left to right) 1.Wiener > 725 mV(pp), 2.Bellinix > $400mV(pp)$, 3.Droege 200mv (pp).

Stability (1 week) / Load when Driving Long Cables

The voltage stability test was performed with and without load switching for a period of one week.

Magnetic Field

The Bellinix, DC-DC power supply was tested in a 3 Gauss magnetic field at Fermilab. The system parameters were 2 KV at 200 μA. No change in the output of this power supply was observed.

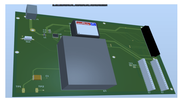

Figure 7. Testing board Belinix DC-DC power supplies with single channel.

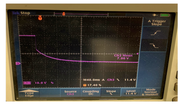

Figure 8. Crowbar response time of DC-DC using switching between 2Kv to 0v

Final HVDS for Station

The High Voltage Mother Board (HVMB) for one station. A total eighteen HVMB are required for whole Mu2e Tracker system.

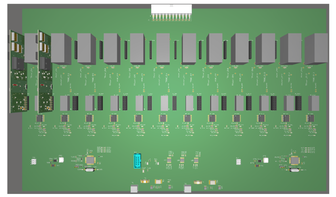

Figure 9. HVMB which for a station contain 12 smart switch's with independent HV channel, two ardiuno chips control individual plane and Raspberry Pi connection for the EPICS system.

Conclusion

In summary, this poster addressed the design and development of a high-efficiency HV distribution system which for each panel distributes and controls, monitor HV from a single HV input line into six output channels and 12 independent HV power system. It documents the development of an intelligent distribution control using a smart switch (SS) to provide voltage, crowbar, and current monitoring. The applications of this system were tested under conditions expected in the Mu2e experiment. These tests included vacuum out-gassing in a 0.01 Torr vacuum, and the stability of the 2 kV high voltage distribution in a HV system with long cables, induced noise, and HV current switching. The application of a DC to DC converter was successfully demonstrated. The experimental results all show satisfactory performance.

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References

[1] Mu2e Collaboration. Mu2e conceptual design report. Technical Report FERMILAB-TM-2545, Nov 2012.