Electronic Switch Implementation to a Particle Physics Data Acquisition Box

Ange Compere
Physics and electrical engineering, Physics dept.
Mentors: Dr. Raul Armendariz, Dr. Corey Stallerman
QCC Undergraduate Research Day 2024

Abstract

The City University of New York (CUNY) Cosmic Ray Muon Detector Array refers to a network of detectors that will be set up across CUNY campuses, specifically designed to detect cosmic ray muons. At Queensborough Community College, the physics department is building a cosmic ray detector for undergraduate research. They aim to create an array of detectors in multiple sites across New York. Every detector consists of three main components: a polyvinyl toluene plastic scintillator plate to detect a charged particle by converting its energy to a flash of faint light, a photomultiplier tube (PMT) to convert the light flash into an electrical pulse, and a data acquisition (DAQ) board to record the time when a particle hits the detector. Basically, the muon detector uses sheets of specialized plastic with fluorescent hydrocarbon molecules. Charged muons that pass through these sheets ionize the molecules which emit photons. These photons can be detected using photomultiplier tubes, which convert the muon energy to electrical pulses. The DAQ electronics box includes various components like a perforated electronics breadboard, GPS receiver, an Arduino Mega, Raspberry Pi, 20V to 5V DC-DC buck converter that convert the received electrical pulses into a voltage that is read by the Arduino. The DAQ electronics box and photomultiplier tubes are powered from the same power supply. However, each component requires a different voltage. The DAQ box needs a fixed 15V. In contrast, the PMT requires a variable voltage to function correctly, as any fluctuation could affect its performance, which is critical for its sensitivity and reliability. The Arduino, Raspberry Pi, and GPS receiver on the other hand, need to be turned off whenever there is a change in its software or GPS complication. To manage this, a switch is installed to separate the PMT circuit and Arduino circuit.

CIRCUITRY OF DAQ BOARD

Every detector consists of three main components: polyvinyl toluene plastic scintillator plate, photomultiplier tube (PMT) and data acquisition (DAQ) board. The DAQ board circuitry mainly consist of the Muon Data Acquisition System and the PMT. The Muon Data Acquisition System electronics box includes a perforated electronics breadboard that contains a GPS receiver, two LM137 variable regulators, two test points, capacitors, ambient temperature and pressure sensors, LCD counters, voltage test points and terminal block. It is connected to the Arduino Mega, Raspberry Pi, 20V to 5V DC-DC buck converter and transform the received electrical pulses into a voltage that is read by the Arduino.

Figure 1: DAQ Electronics Box

As shown in figure 1 each component is connected to one or another, and they are all powered by the same power source. The terminal Block receives 15V of power into the box from the power supply, then is alimenting the fan, LM 317's, DAQ FE, and the Muon Data Acquisition system.

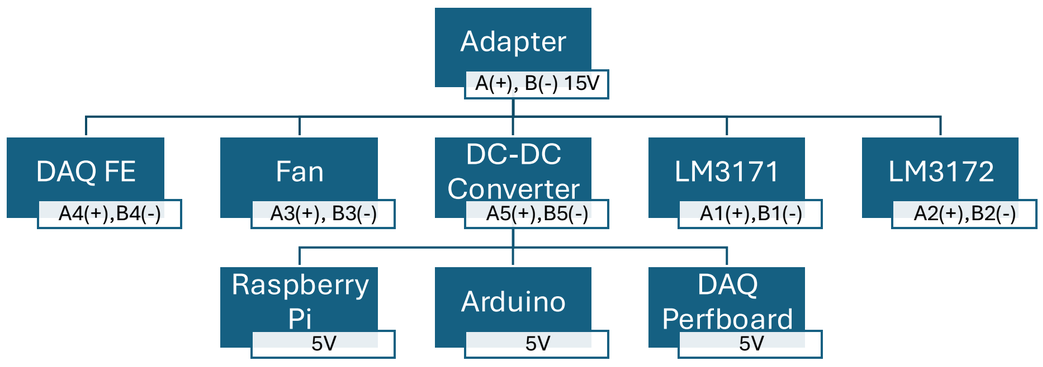


Figure 2: DAQ powering

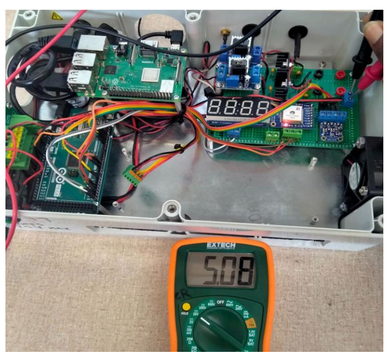


Figure 3.1: Voltage of Perfboard

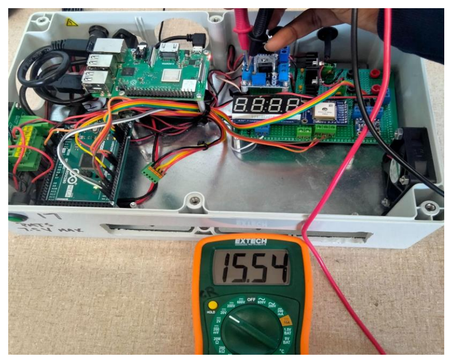


Figure 3.2: Voltage of LM 137

The Muon Data Acquisition System

In the development stage of the DAQ box it was concluded that the whole circuit needed different voltages to operate (figure 3). Therefore, a DC- DC converter was used to convert the input power of 15V from the terminal block to 5V for the Arduino. The cosmic ray electrical pulses are measured and recorded with date, time, temperature and coordinate. However, if the system has technical issues the power must be shut off to part of the circuitry but not the Photomultiplier tubes (PMT). To remediate this problem, we implemented a switch which will serve as an isolating device between the Muon Data Acquisition System and the PMT.

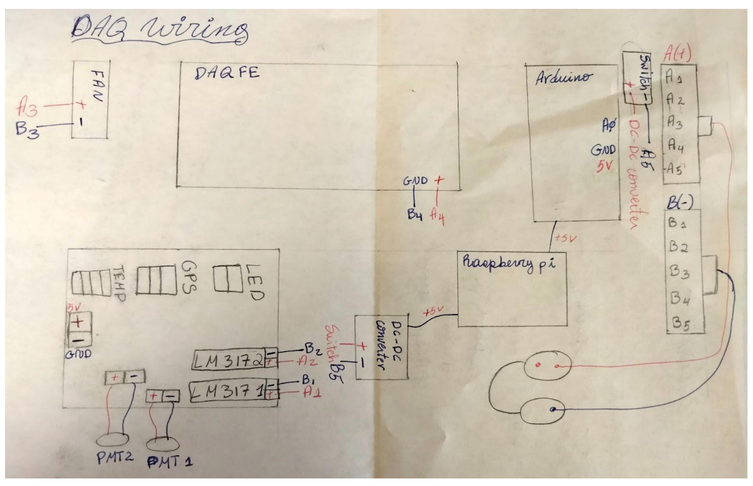
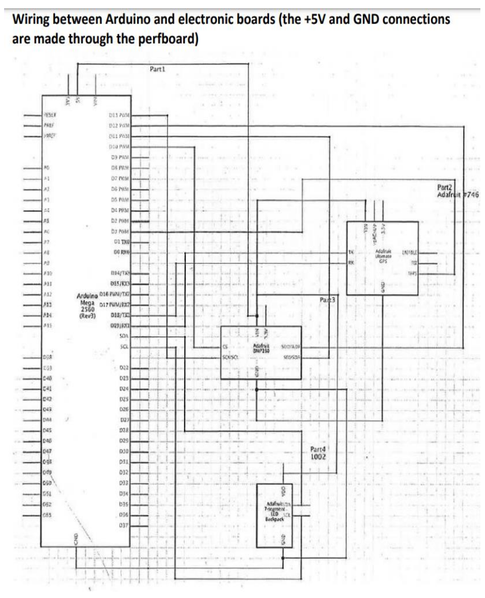


Figure 4: DAQ Wiring



Switch Installation & Results:

In an electronics box, a switch implementation depends on certain data, but more precisely the minimum current and voltage the switch will need to operate.

After the installation of the switch the DAQ electronics box and photomultiplier tubes can work independently while being powered by the same power supply. Permitting a much safer ground to edit the Muon Data Acquisition system without damaging the performance of the PMT.

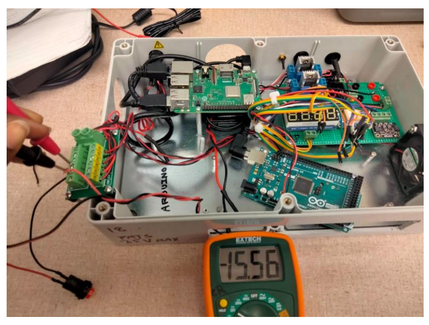


Figure 5.1: Voltage through the switch

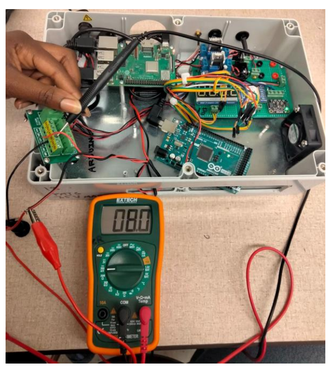


Figure 5.3: Voltage Drop

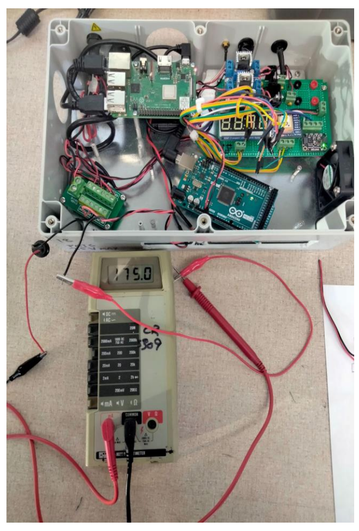


Figure 5.2: Current through the switch (mA)

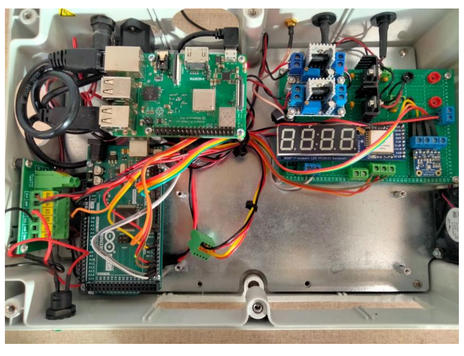


Figure 6: Updates DAQ box

Conclusion:

In conclusion, with the implementation of the switch to the Data Acquisition electronics box and photomultiplier tubes that are powered from the same power supply are safely separated. This solution guarantees that both devices will operate optimally without interference from one another while still being connected to the same power source.

Acknowledgment :

A very special thanks to Dr. Raul Armendariz and Dr Corey Stallerman for this opportunity as well as their help, guidance and mentoring. I'd like to thank my research partner Jude Addinus and Shorn Grant for their help in completing the project. Final thanks to Queensborough Community College Physics Department for their immense support and resources to conduct this research.

QUEENSBOROUGH COMMUNITY COLLEGE CUNY