LIP-STUDENTS-22-24

Upgrade of the ATLAS Tile Calorimeter High Voltage System

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Abstract. The upgrade of the ATLAS detector to work at the new high-luminosity LHC (HL-LHC) requires the replacement of all the electronics of the Tilecal calorimeter such as the high voltage (HV) system that feeds 10000 photomultipliers (PMTs). The new boards containing the HV power suppliers require testing which will be done by designing a printed circuit board (PCB) with a 48 relay matrix capable of testing each power supply individually.

KEYWORDS: LHC, ATLAS, PMT, HV, relay matrix

1 Introduction

1.1 The ATLAS detector

The ATLAS detector is the biggest detector from the LHC, at CERN. It has a cylindrical shape built around the point where the collisions occur, followed by a pixel/SCT detector and transition radiation tracker which together provide tracking information. Then there is the central solenoid magnet which produces a 2 T magnetic field. After there is a liquid argon calorimeter, where photons, electrons and hadrons typically lay their energy in the form of energy clusters (showers) and a tile hadronic calorimeter (Tilecal), where hadrons deposit their energy. Continuing outwards, there are the muon spectometers, consisting of thin gap chambers, resistive plate chambers, monitored drift tubes and cathod strip chambers surrounded by three toroid magnets which generate a field of up to 3.5 T (a full description can be found in [1]).

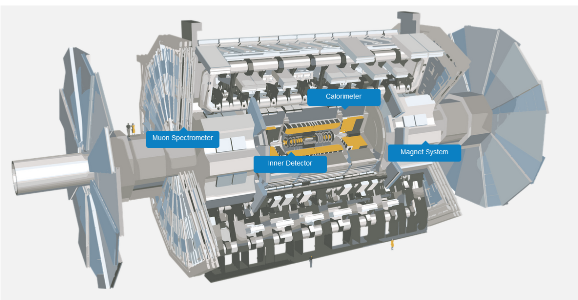

Figure 1. Schematic view of the ATLAS detector.

1.2 Photomultiplier Tubes

Photomultipliers are among the most sensitive of all light sensors and are used to detect faint light. PMTs are typically built with an evacuated glass housing (using an extremely tight and durable glass-to-metal seal), containing a photocathode, several dynodes, and an anode. Incident photons strike the photocathode material and electrons are ejected from the surface as a consequence of the photoelectric effect. These electrons are directed by the focusing electrode toward the electron multiplier consisting of several dynodes each holding a higher potential than the preceding one which creates a chain photoelectric effect essentially multiplying the current produced by the incident light by up to 10^8 times its original value. The HV system that feeds the Tilecal PMTs is old and will be unable to survive the radiation levels of the HL-LHC operation. A new HV system [2] is being developed for the upgrade of the detector.

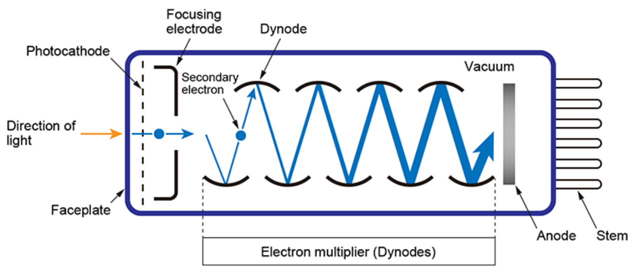

Figure 2. Schematic view of a PMT. [3]

1.3 HV regulation boards and the multiplexing board

The HV needs to be regulated individually for each of the 10000 PMTs. For that purpose, HVRemote boards with 48 HV channels are used. Each channel needs to be calibrated in order to be correctly operated. To avoid the usage of 48 voltmeters in the voltage calibration procedure, a HV multiplexer with 48 input channels is needed, allowing the usage of a single voltmeter to calibrate the HVRemote board. The purpose of this work is the design of a board to do the multiplexing of the 48 HV channels using relays.

2 Design of the HV multiplexing board

The goal of the multiplexing board is to select only one of the 48 channels of the HVRemote board and feed it to a voltmeter. Selecting one channel at a time will allow to do

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the scan of all the 48 channels in a short time period for calibration, or to keep monitoring them for hours in runs to check the stability of the high voltage outputs.

2.1 Common emitter amplifier configuration

The common emitter (CE) amplifier configuration uses a bipolar-junction-transistor (BJT) and offers high current gain (typically around 200), medium input impedance and high output impedance. It is referred to as "common emitter" since the base of the BJT is used as the input terminal, the collector as the output terminal and the emitter as the common terminal.

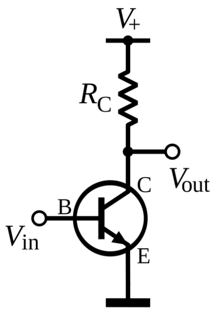

Figure 3. Basic NPN common emitter amplifier circuit. [4]

2.2 Main circuit

The main circuit consists of an NPN transistor in a CE amplifier configuration with the objective of amplifying the current of the input signal in order to trigger the relay to which it is connected. By triggering the relay, it is then possible to measure the voltage at its terminals and verify if it is functioning correctly. This circuit is then multiplied by 48 to fit 48 relays in the board and since only one relay is to be tested at a time, three 8-bit multiplexers are used for selection. A diode is also added in each circuit to prevent backfeed.

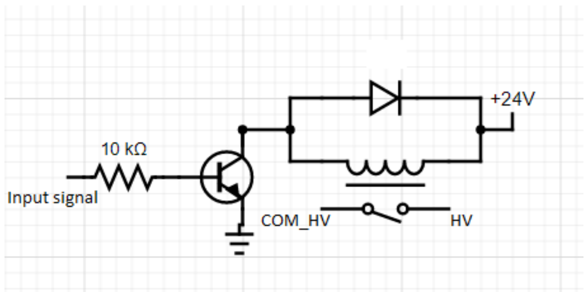

Figure 4. Main circuit schematic.

2.3 PCB design

The program Altium Designer was used to design the board schematic and the PCB itself. The schematic was divided into 5 different pages: power and signal input/output, HV input, MUXs and transistors and the last 2 pages contained the relays. The PCB has six layers and

was designed by importing the components and connections from the schematic and placing them in the following order: DB-25 power ports at the extremities of the board (two in each side), six lines of four relays and diodes in each half of the board, right besides the power ports, and finally a central column with the MUXs and transistors. After placing all the components, they were then routed using three of the six layers: Signal up, signal bottom and HV. The remaining three layers were two GND layers and a power layer which used power polygons to power the transistors and MUXs. (Refer to the figure 5 below for more detail.)

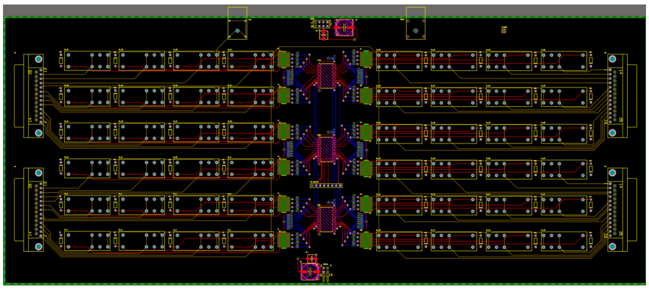

Figure 5. Design schematic of the PCB.

3 Results and Conclusions

At the time of writing this article the designed board was not yet utilized and therefore it is not possible to conclude about its functionality.

Acknowledgements

With the design of this board I developed skills in PCB designing, learning details and good practices to keep in mind when designing a PCB and working with HV. I also learned how to use the professional tool "Altium Designer". For this I would like to thank my supervisors Luís Gurriana, Prof. Guiomar Evans and Prof. Agostinho Gomes for all the guidance and help in developing this project as well as FCUL and LIP for providing me with this opportunity and the space to work on it.

References

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[2] A. Gomes et al., JINST 17 C01061 (2022)

[3] M. Precision, https://www.matsusada.com/application/ps/photomultiplier_tubes

[4] Wikipedia, https://en.wikipedia.org/wiki/Common_emitter