LIP-STUDENTS-23-17

Development of safety algorithms for the ATLAS-HGTD

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Abstract. The objective of this work was to map the correspondence between the input interlock signals (from NTC sensors and from the ATLAS Detector Safety System) and the corresponding power supply channels that must be switched off if the temperature rise. For that, a C program was created that determined the location of the NTC and indicated the specific Low Voltage and High Voltage connections for the LGADs around that NTC.

KEYWORDS: Interlock, NTC

1 Introduction

ATLAS is the largest volume particle detector ever constructed at the Large Hadron Collider (LHC).

It has significant dimensions, 46 meters long, 25 meters high and 25 meters wide, weighing approximately 7000 tons. It plays a key role in the search for new elementary particles and the investigation of the fundamental principles of the universe.

To be able to extract physics information at the High Luminosity LHC, where the number of simultaneous collisions is expected to be huge, so challenging the correct energy and momentum reconstruction of the partivles reaching the detector, it was necessary to build the High Granularity Timing Detector (HGTD). The purpose of the HGTD is to measurement of track time with an accuracy of better than 50 ps and provide information about luminosity. (The particles appear in their graphical representation on top of each other, so it's necessary to separate them in the order of the time they are detected by the sensor).

2 The High Granularity Timing Detector (HGTD)

The HGTD consists of two hermetic vessels. These vessels have cylindring shape with inner holes. Inside each vessel, there are two cooled disks on both sides at which Low-Gain Avalanche Detectors (LGAD) are mounted. The active detector elements is made of this modules.

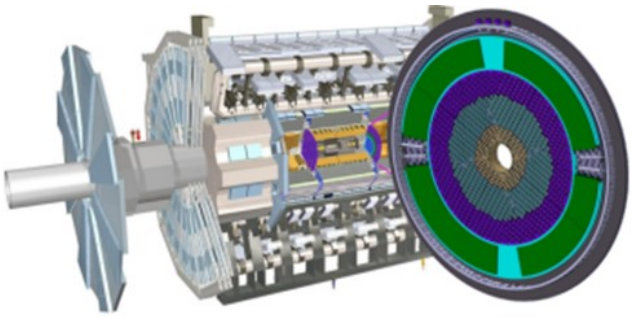

Figure 1. Position of the two HGTD vessels in ATLAS.

HGTD sensors use Low Gain Avalanche Detector (LGAD) technology, connected via flex cables to Peripheral Electronic Boards (PEB) for control. PEBs are used to monitor temperature and voltage data. These sensors are mounted in electronic boards and receive high voltages (900 V). Low Voltages for digital components are also needed.

Each quadrant and side of the HGTD is handled by five different PEBs, as shown bellow.

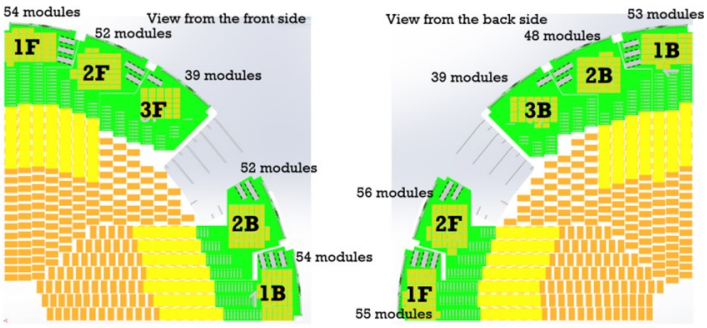

Figure 2. Distribution of PEBs on a disk.

There are a total of 160 PEBs, 80 on each vessel and 8032 modules receiving signals from the LGADs (Low Gain Avalanche Detectors).

In terms of applied voltage, there are 320 Low Voltage channels (2 per PEB), distribuited by 40 Low Voltage

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modules, so each module having 8 Low Voltage channels and, finally, 40 High Voltage crates. These crates hold to a set of modules, approximately 16 modules each.

3 Interlock

The HGTD Interlock System (HIS) is a standalone safety system that protects the detector against a variety of risks. There are primarily 2 kinds of dangers to be handled by interlocks:

- Overheating (mainly a risk to the detector and equipment).
- Danger to the entire detector due to unstable beam, a failure in the cooling system, or smoke etc.

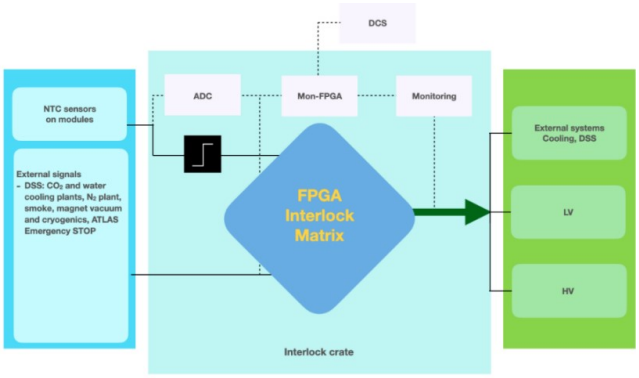

Figure 3. Diagram Illustrating the Operation of the Interlock Safety System.

In Figure 3 we have a diagram that explains how the Interlock System works. On the left are the interlock detectors, i.e, the detectors that recognize threats.

On the right side of this diagram are the devices that must be switched off by the Interlock System in the event of danger.

The central part is the interlock crate, which contains an FPGA, the program of which defines the interlock matrix.

For debugging purposes, the monitoring system keeps track of analog values from temperature sensors, signals transmitted to power supplies, and all signals from/to external systems.

One of the sensors that allows these threats to be recognized are NTCs. These are Thermistors with a negative temperature coefficient (NTC) will be used as temperature sensors on module FLEXes due to their high radiation hardness and the large signal they produce, which allows signals to be transmitted over long distances. These NTCs will be connected to the PEBs. However, due to cable limitations, there will only be one NTC for every 9 modules.

The HGTD Interlock system consists of one Main Interlock Crate (MIC) and 4 Local Interlock & Safety SYstem (LISSY) crates.

The LISSY houses one Interlock Logic (ILock-FPGA) module, one Monitoring (MON-FPGA) module, one Global Safety Signals (GSS) module, and up to 17 IO modules: Temperature to Interlock (T2I) modules and interlock output (OUT) modules.

4 Mapping the NTCs to the associated LV and HV power supplies

After collecting all the information about the HGTD, it was necessary to organize all the components and associate them with an NTC so that they can be unambiguously disconnected when necessary.

To do this,a table that associates the components related to a disk has been created. (Remember that each vessel has two disks and there are two vessels in total).

PEB	nº of PEBs	LV channels	nº of modules (Front-side)	nº of NTCs (Front-side)	nº of modules (Back-side)	nº of NTCs (Back-side)
1F	8	16	216	24	220	24
2F	8	16	208	23	224	25
3F	4	8	156	18	-	-
3B	4	8	-	-	156	18
2B	8	16	208	23	192	21
1B	8	16	216	24	212	24
Total	40	80	1004	112	1004	112

Figure 4. Distribution for one disk.

Next, it was necessary to separate the Low Voltage channels into modules and distribute the High Voltage crates. This is essential because of the Interlock functionality with granularity of 6–8 channels.

First vessel				Second vessel			
nº of PEBs	LV channels	LV modules	HV crates	nº of PEBs	LV channels	LV modules	HV crates
16	32	4	4	16	32	4	4
16	32	4	4	16	32	4	4
8	16	2	2	8	16	2	2
8	16	2	2	8	16	2	2
16	32	4	4	16	32	4	4
16	32	4	4	16	32	4	4

Figure 5. Distribution for one disk.

Finally, a C program that determined the location of the NTC and indicated the specific Low Voltage and High Voltage connections for the LGADs around that NTC has been created. To achieve this, a name to each NTC has been assigned.

Developed the following nomenclature was established:

VC2BPEB2BNTC607

The first two letters indicate the vessel in which the NTC is located (VC - Vessel C). The following letters indicate the quadrant where it is located (2B - Quadrant 2B), followed by the type of PEB to which the NTC is connected (PEB2B - PEB type 2B). Finally, we have information about the number of NTC (NTC 607).

After naming each NTC, it was only necessary to associate it with a Low Voltage module and a High Voltage crate.

With this program, when an NTC sends a danger signal, it's possible to determine immediately which LV module and HV crate have to be disconnected.

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