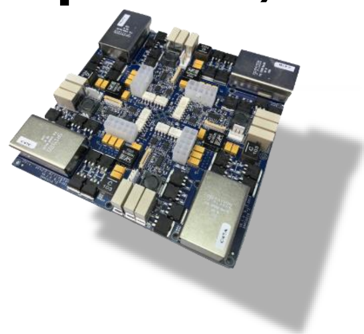
Low Voltage Power Supply production, hardware upgrade and testing for the ATLAS TileCal Front-End Electronics system

Edward K. Nkadimeng

Thabo Lepota, Ryan McKenzie, Nkosi Njara, Roger van Rensburg, Othmane Mouane, Charles Sandrock, Bruce Mellado

HEPP Workshop 2020, University of Venda



Institute for Collider Particle Physics

University of the Witwatersrand

ATLAS Experiment

NRF National Research Foundation

Outline of talk

I. ATLAS detector
   I. TileCal readout system
   II. Why upgrade?
   III. Timeline

II. Project Overview

III. Wits LVPS brick description and Checkout process

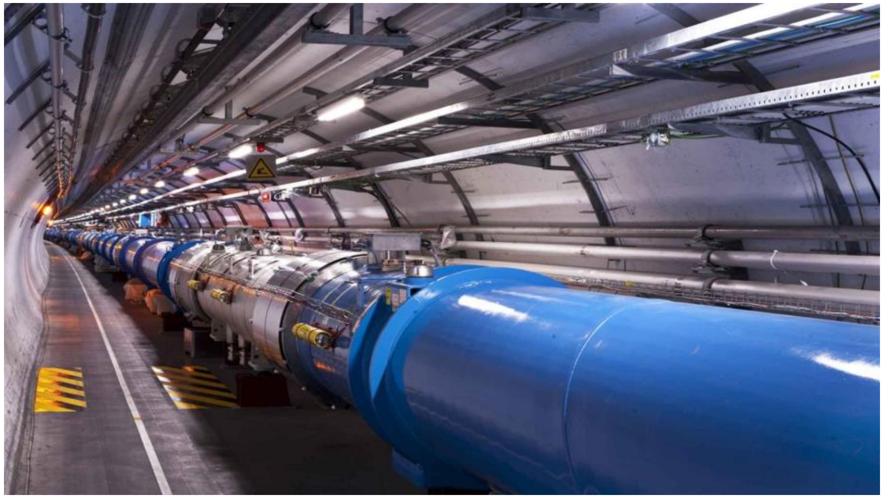
IV. Quality assurance test station and Burn-In station development

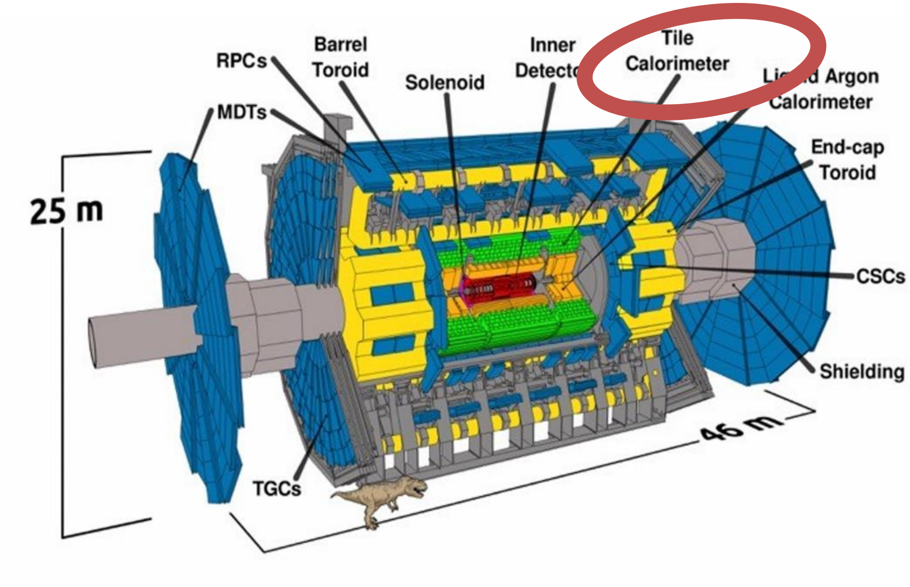
V. Efficiency of the South African LVPS bricks

VI. Summary and Outlook

ATLAS detector

LHC is a particle accelerator that pushes protons or ions to near the speed of light





100 million electronic channels

~ 3 000 km of cables

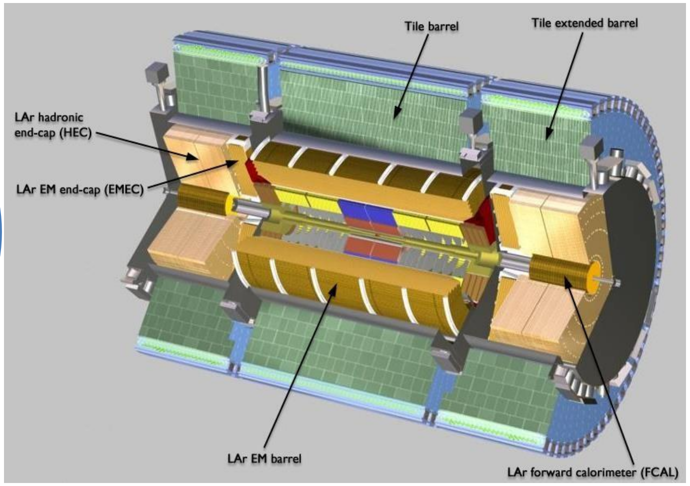
ATLAS WITS responsible for HALF of the Low Voltage Power Supply boards needed for the detector in the Tile Calorimeter

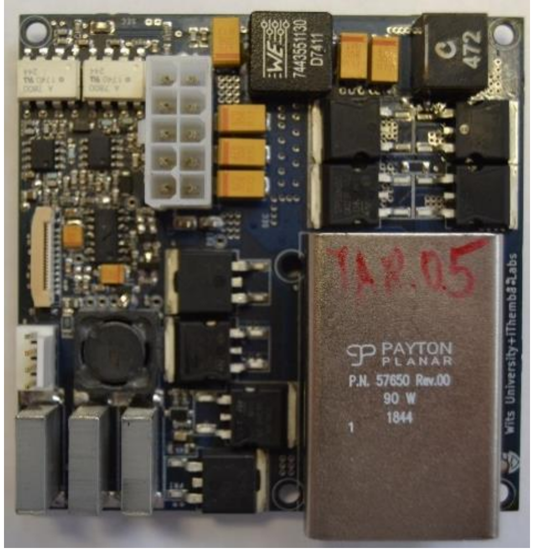
Overview of the TileCal readout system

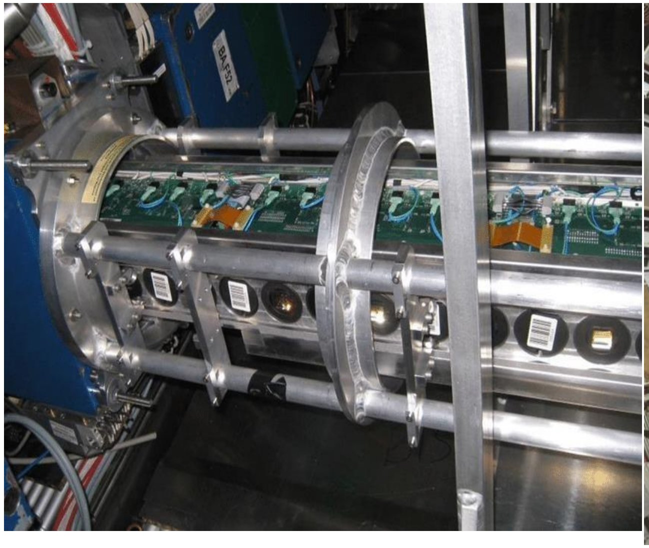
TileCal samples the energy of hadrons as they interact with 500,000 scintillator tiles within the system.

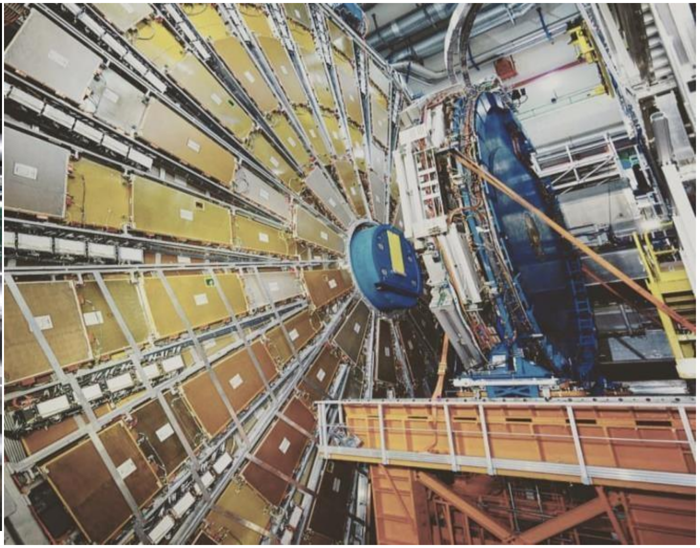
TileCal consists of 4 sections, each comprising of 64 wedge-like segments

LVPS is positioned within a drawer of TileCal to power the detector electronics which are also housed within the drawer.









Why Upgrade?

Increase LHC luminosity to ~ 5 - 7.5 x $10^{-34}cm^{-2}s^{-1}$ at Phase-2

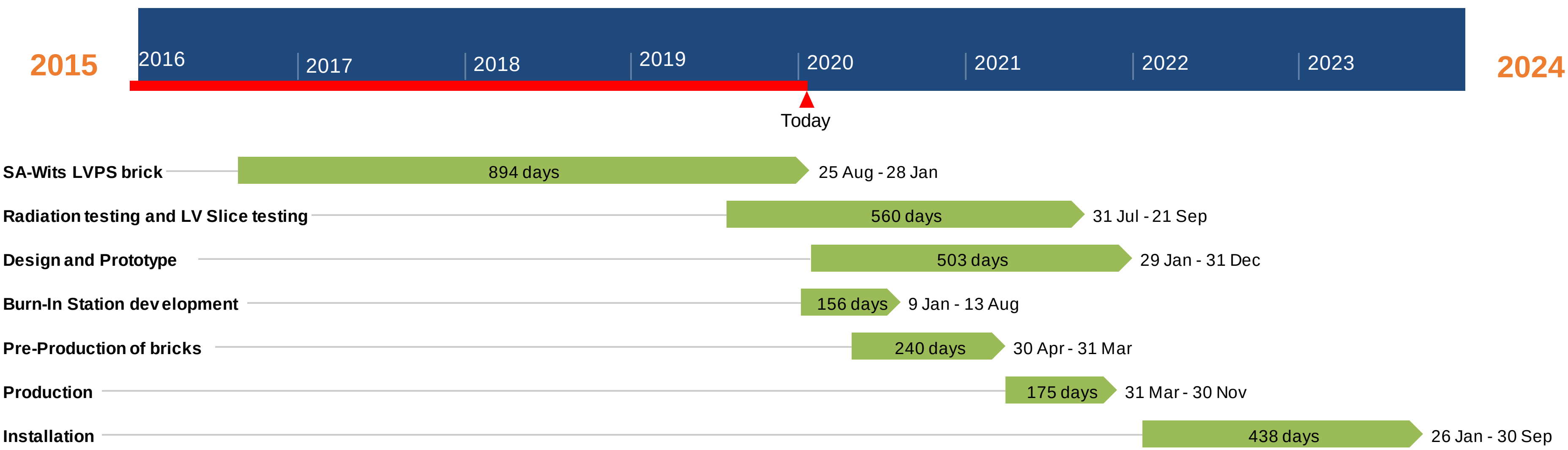
Most front-end and back-end electronics need to cope with higher data rates and provide higher reliability and robustness

- Require higher radiation tolerance for the on-detector electronics
- Avoid single point failures

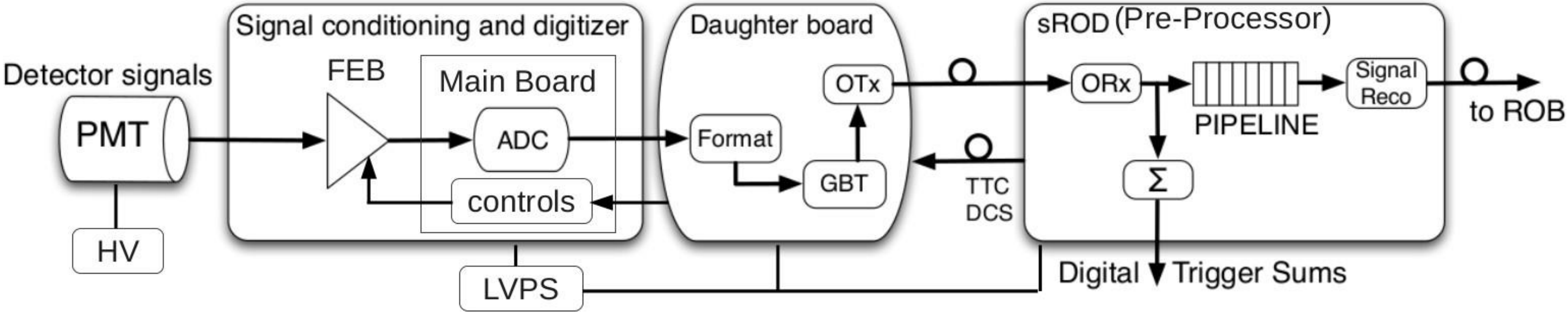
- More specifically (for this project) we intend to develop a quality assurance test-station and Burn-In station for testing the latest version of a switch-mode power supply that supplies power to the front-end electronics. The new design uses just one type of brick, which means that all bricks convert the 200 V input to a 10 V output.

All TileCal electronics must be replaced to satisfy new requirements

Timeline of events for LVPS project in SA



Project Overview



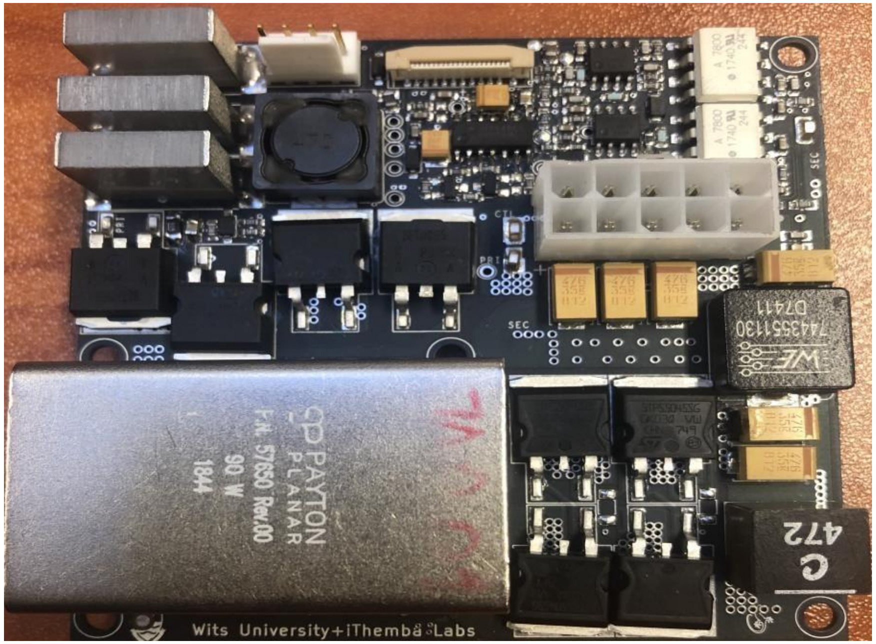
- There are eight DC/DC single-output power supplies (**bricks**) transforming a 200V DC input into a +10V feed to the Main Boards on the Tile drawers, which are required to operate the TileCal. A total of 1024 (half needed for entire detector) will be produced by **Wits University.**
- An initial quality assurance test station as well as a Burn-In type station would be developed at Wits.

Production of Thermal posts are used for heat transfer from the important components

There are **14** thermal posts per LVPS brick, from which **8** are metalized to have contact with power. (See Othmane's talk)

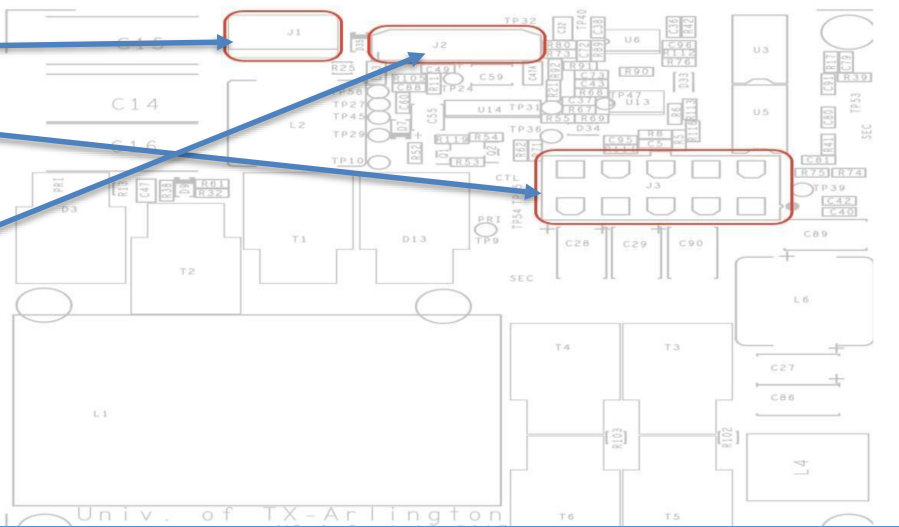
Wits LVPS brick description

- The LVPS brick is a 6 layer board with dimensions 80.26 mm^2
- A shielded transformer is used to provide isolation from input to output of brick
- Brick has mounting holes for attachment to cooling plate through use of Al Oxide thermal posts



There are three connectors:

1. 4 pin – 200 V
2. 10 pin – 10 V to Harting connector on LVPS Box
3. 20 pin – connects to ELMB MB through a ribbon cable



LVPS Checkout process

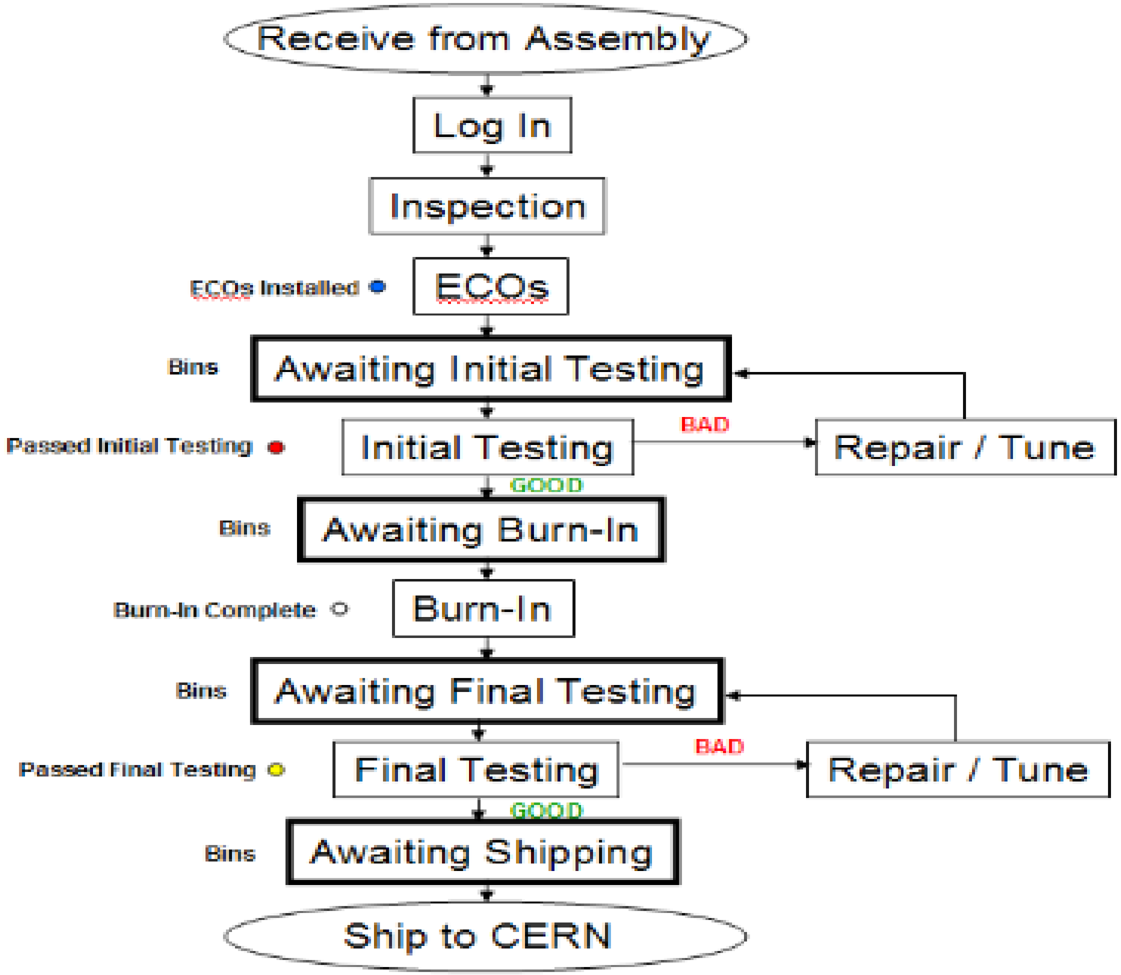
1. **Initial Tests**
   - Full suite of 13 tests, automated by computer
   - Results stored in data files for each brick
   - Repair/Tune if needed

2. **Burn-In Station**
   - 8 hours, under load, monitored continuously by computer.

3. **Store results on LVPS database**

http://www.particle.cz/work/TileDB2/)

4. **Ship to CERN**



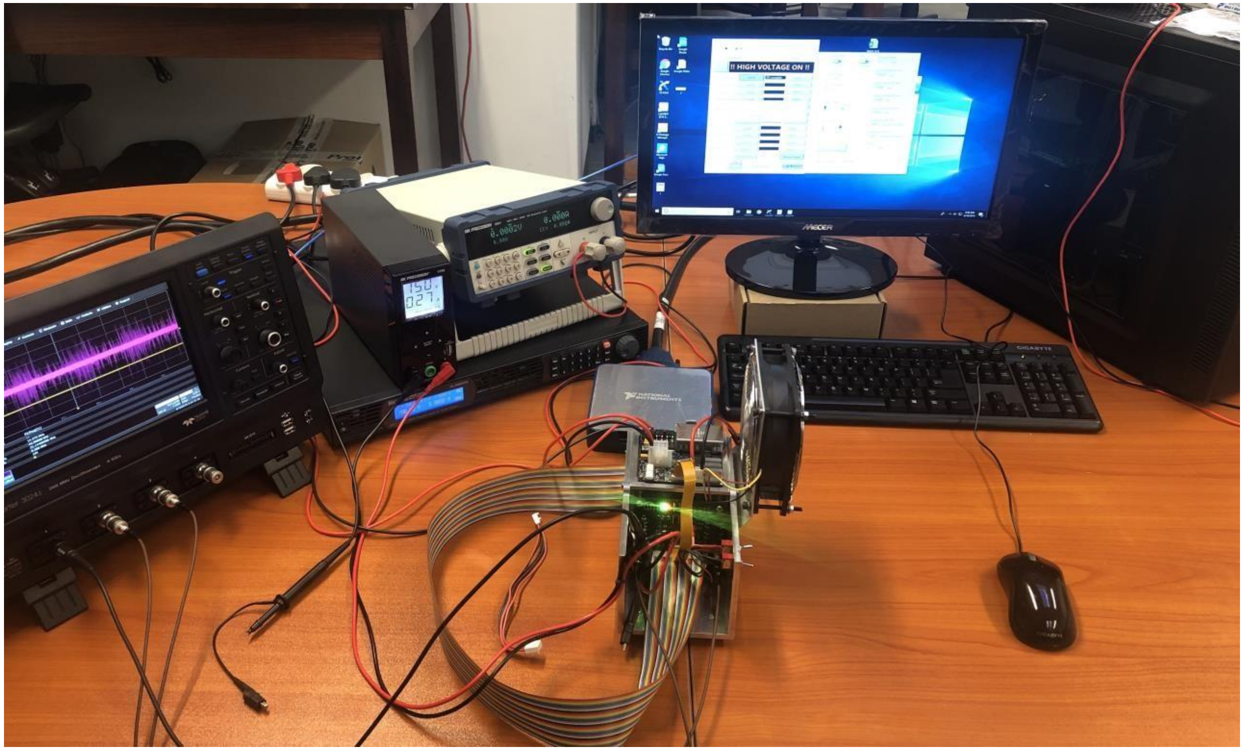
Development of Wits Test station for LVPS Production

Eleven separate tests in total completes these tasks, each communicating with several lab instrumentation devices. The development of the Wits test station is successful and currently being operated at the Wits School of physics.

A few notable metrics we are measuring are the system clock and its jitter.

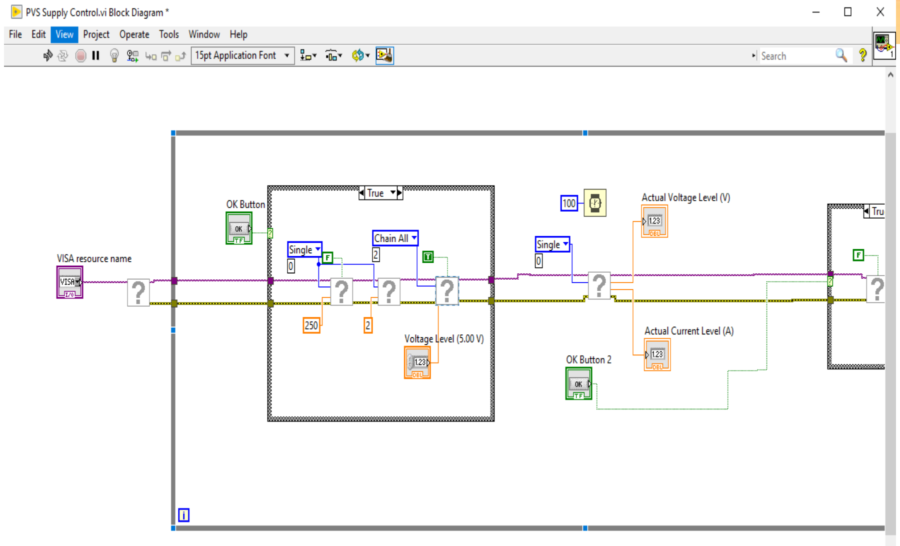
After production, each brick goes through a Quality Control procedure to ensure the bricks are operating within the operating parameters previously stated.

See Ryan's Talk



Burn-In Station development

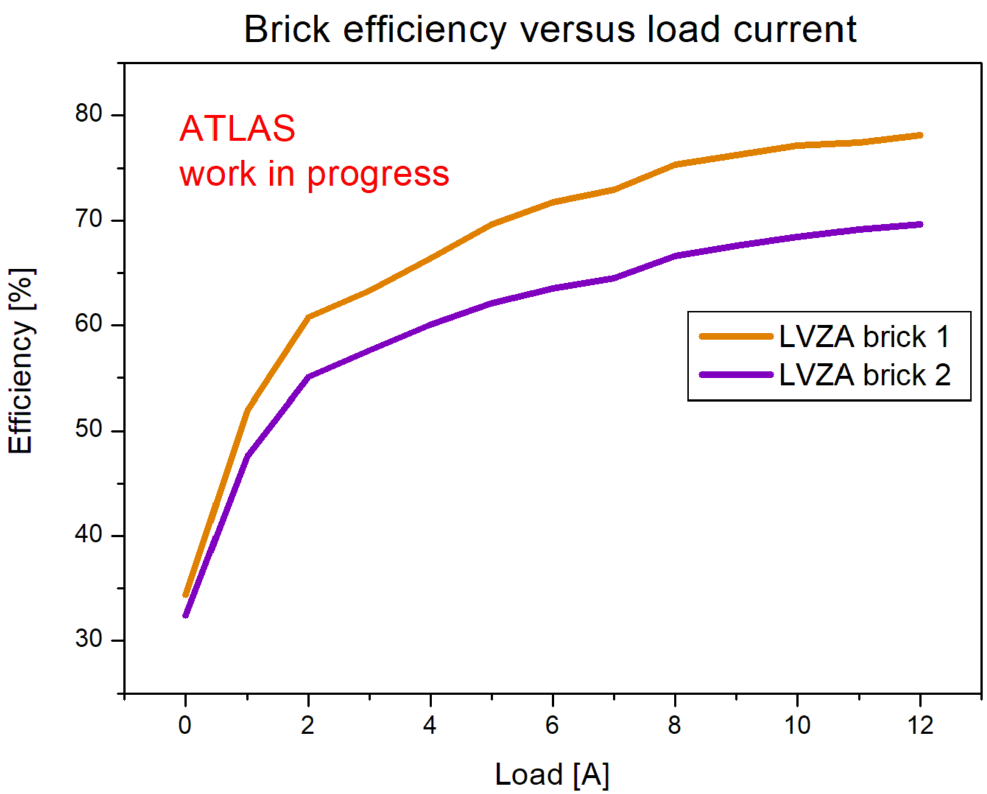
- Test PC set up as well as the PVS high power programmable supply. Awaiting redesign of test bed.
- All drivers and VISA resources are installed.
- Fully programmable and uses subsystem commands for functions.



So far efficiency of South African bricks

The maximum output power from the brick is 150W.

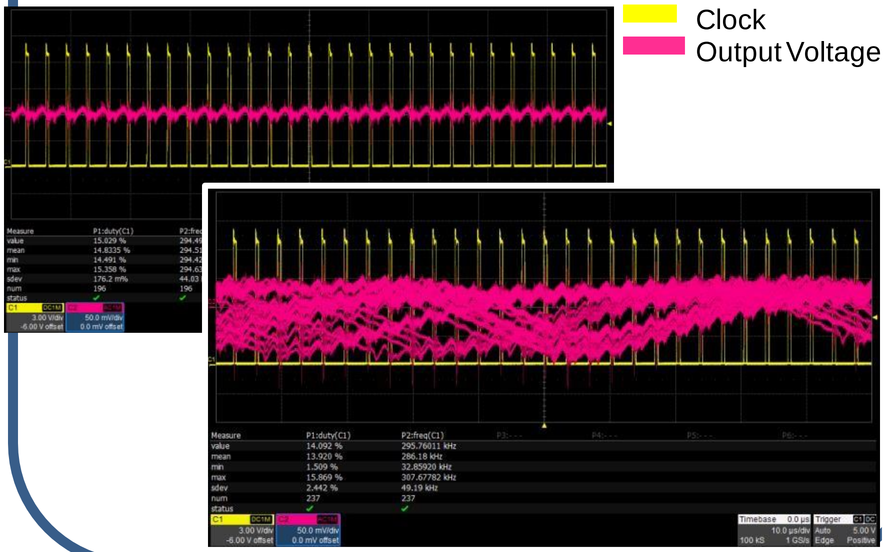
The DC/DC converter design enables high efficiency of energy conversion: 76% for LVZA Wits brick @12A I out, 79% @12A for the 10V version



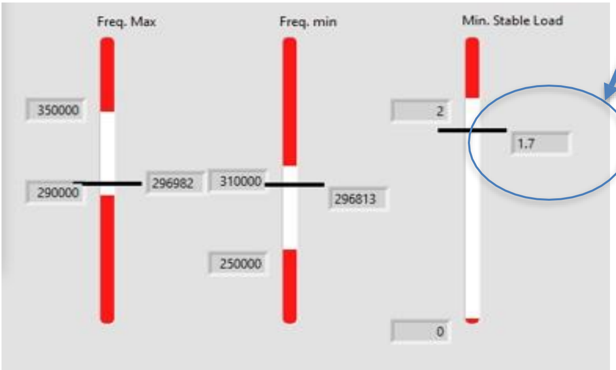
Results continued..

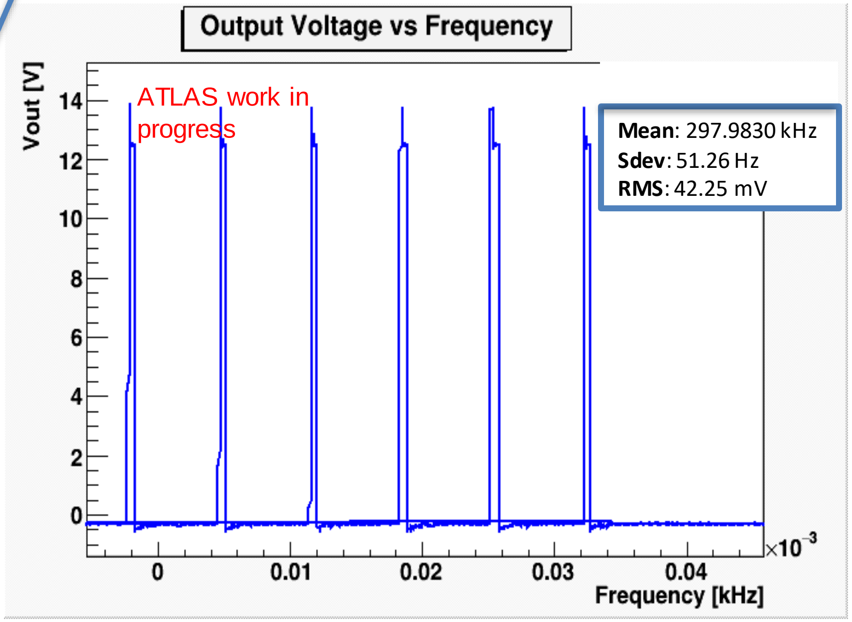
Test #1: Output Continuous Current Conduction

Output voltage ripple is lowest on the brick when current is continuously conducted through the output filter.



Test #1 also checks for the minimum stable load the load is increased gradually from zero to find the minimum stable load.





Summary

We have undertaken this large-scale project to redesign the LVPS bricks for the Atlas Tile Calorimeter front-end electronics.

We have built and tested the LVPS bricks which are manufactured in South Africa and tested at Wits (using the Wits LVPS test station) and have completed the production of **16** bricks with **32** currently in production.

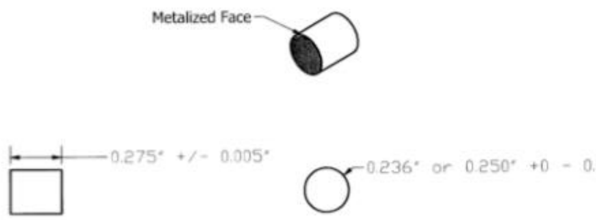
The reliability and stability of the system has been visibly improved with respect to the previous design with the initial test station and ongoing Burn-In Station development.

All the results from **latest** Wits test station are well documented in the technical document.

Ke a leboga/Ndo livhuwa

PCB Assembly and material posts

Jemstech have assembled sixteen boards from Trax and will assemble 32 more. They supply the components too except for the transformers and posts.

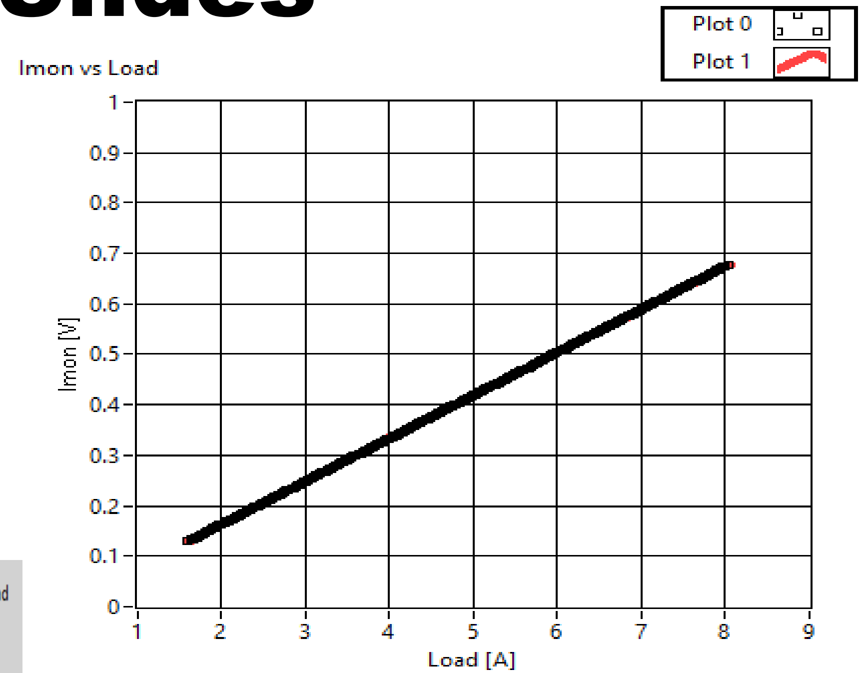


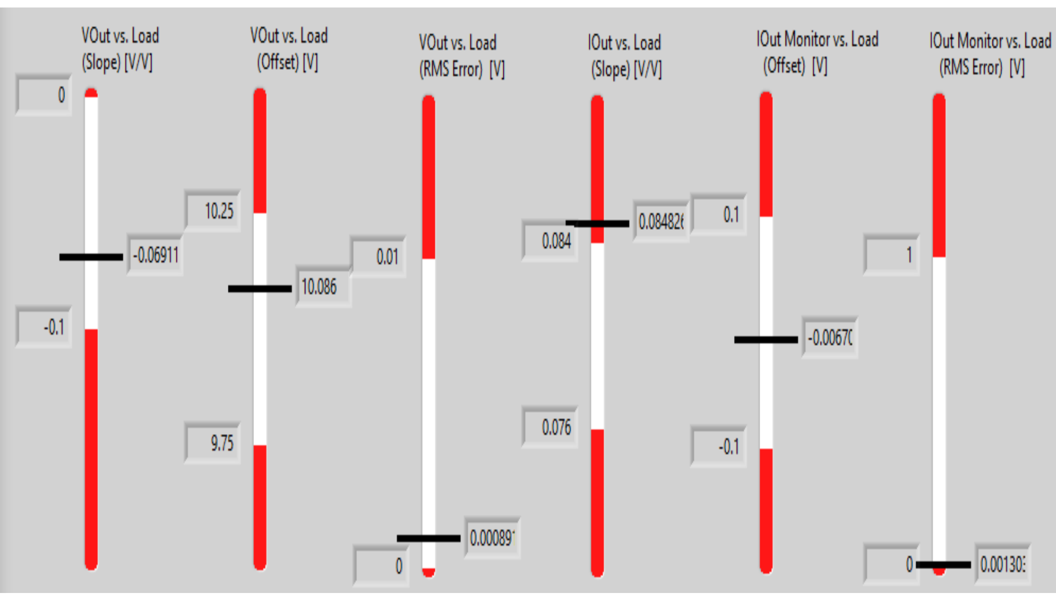
See Othmane's talk on material posts

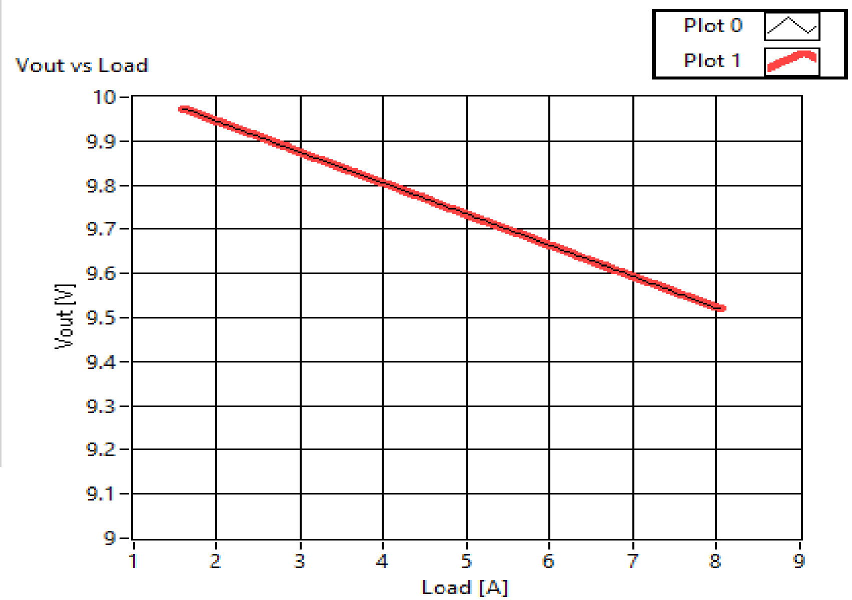
Back Up Slides

Vout / Imon vs Load

The changes of the output voltage and current monitor signal are plotted vs load current.

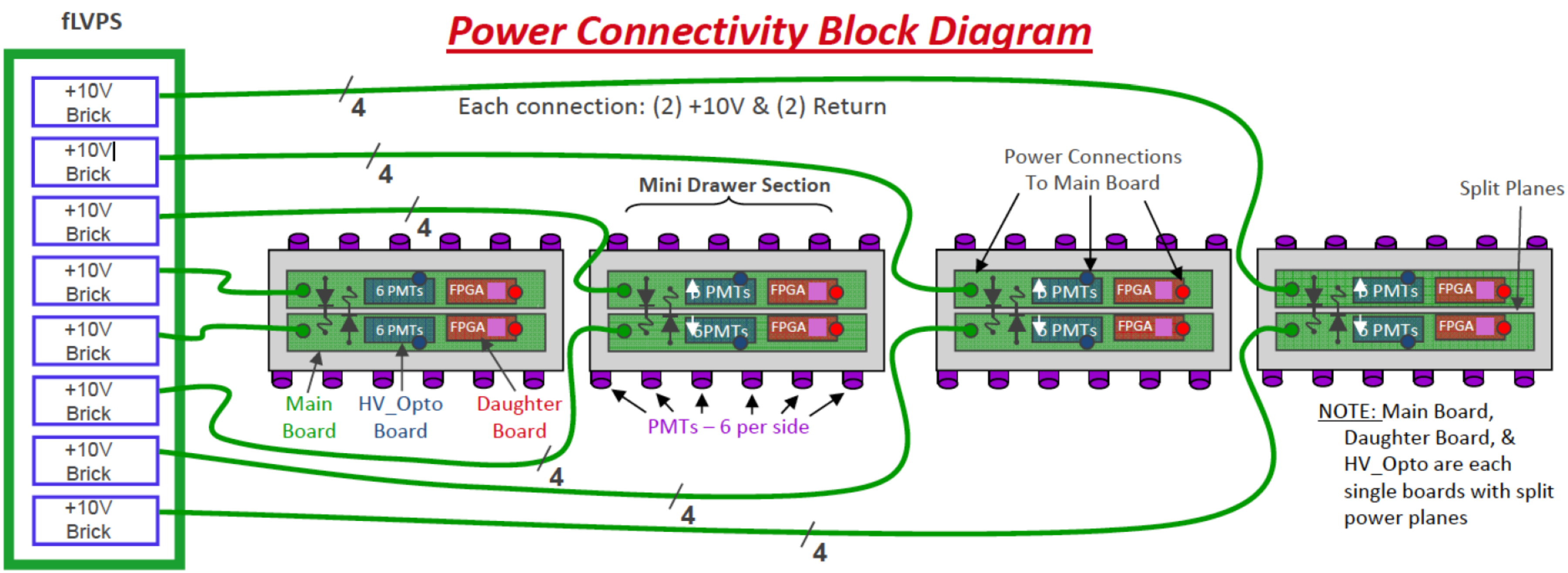






Power up connectivity

- Each brick powers half of a mini-drawer with a fuse and diode-or circuit which allows one brick to operate in redundancy mode and provide power to the entire mini-drawer if the other brick fails.
- As described earlier each bricks powers half of a mini-drawer with a redundancy which allows the brick on the other side to power both halves of the mini-drawer.
- Without the mini-drawer redundancy we lose one PMT on each of the 6 calorimeter cells on one side of the drawer. However each cell is read-out by two PMTs therefore the loss of a bricks results in a negligible impact on physics
- Losing two bricks within a mini-drawer would lead to a loss of 6 calorimeter cells compared to the current design.

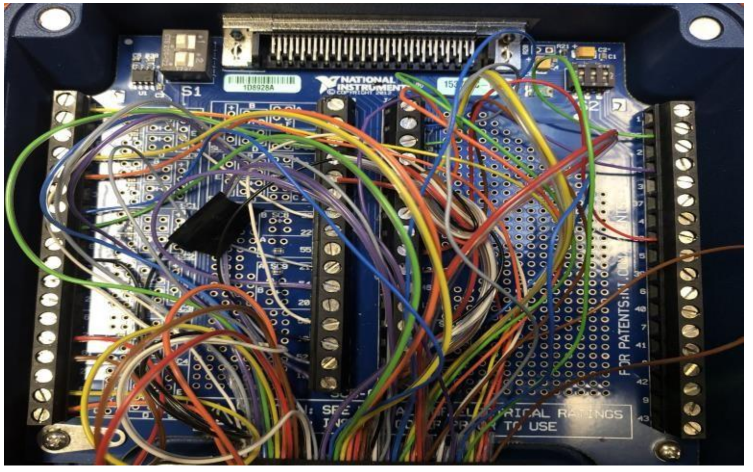


Wits Test stand and DAQ connections

Name or Number
4 pin input connector (J1)
10 pin output connector (J3)
20 pin control and monitoring connector (J2)

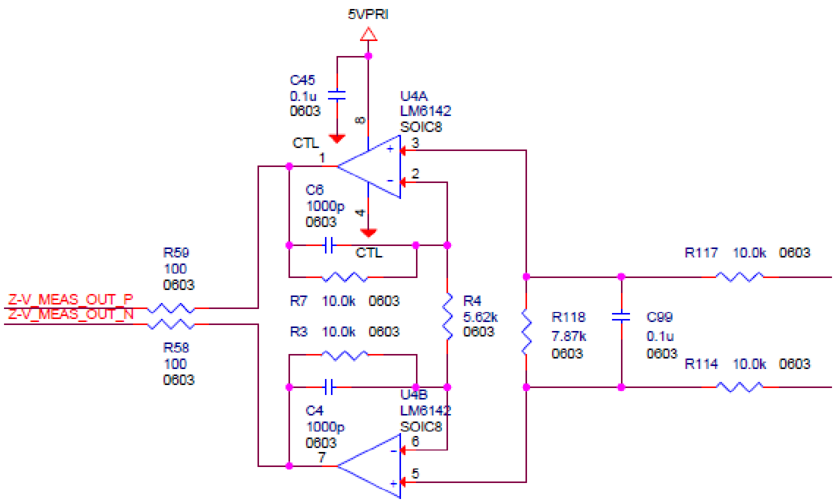
The Wits test mechanical fixture and LVPS brick are successfully manufactured in SA and tested at Wits

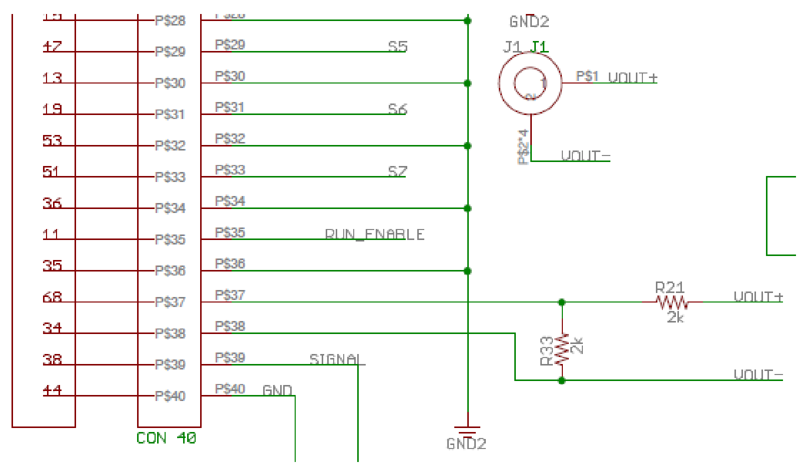
Name	In, Out or I/O	Type of Signal or Max/Min	Num ber	Description
Monitoring signals	Out	DA	6 x 2	Input and output voltage, input and output current. Two temperature measurements.
Startup	In	Digital	1	Startup pulse to turn on the brick. Comes from ELMB motherboard.
Enable	In	Digital	1	Enabling or disabling the brick. Comes from ELMB motherboard.



Measuring differential input

The differential input (Z-V_MEAS_OUT_P and Z-V_MEAS_OUT_N) from a brick is connected to the DAQ to measure the brick output voltage (see below).





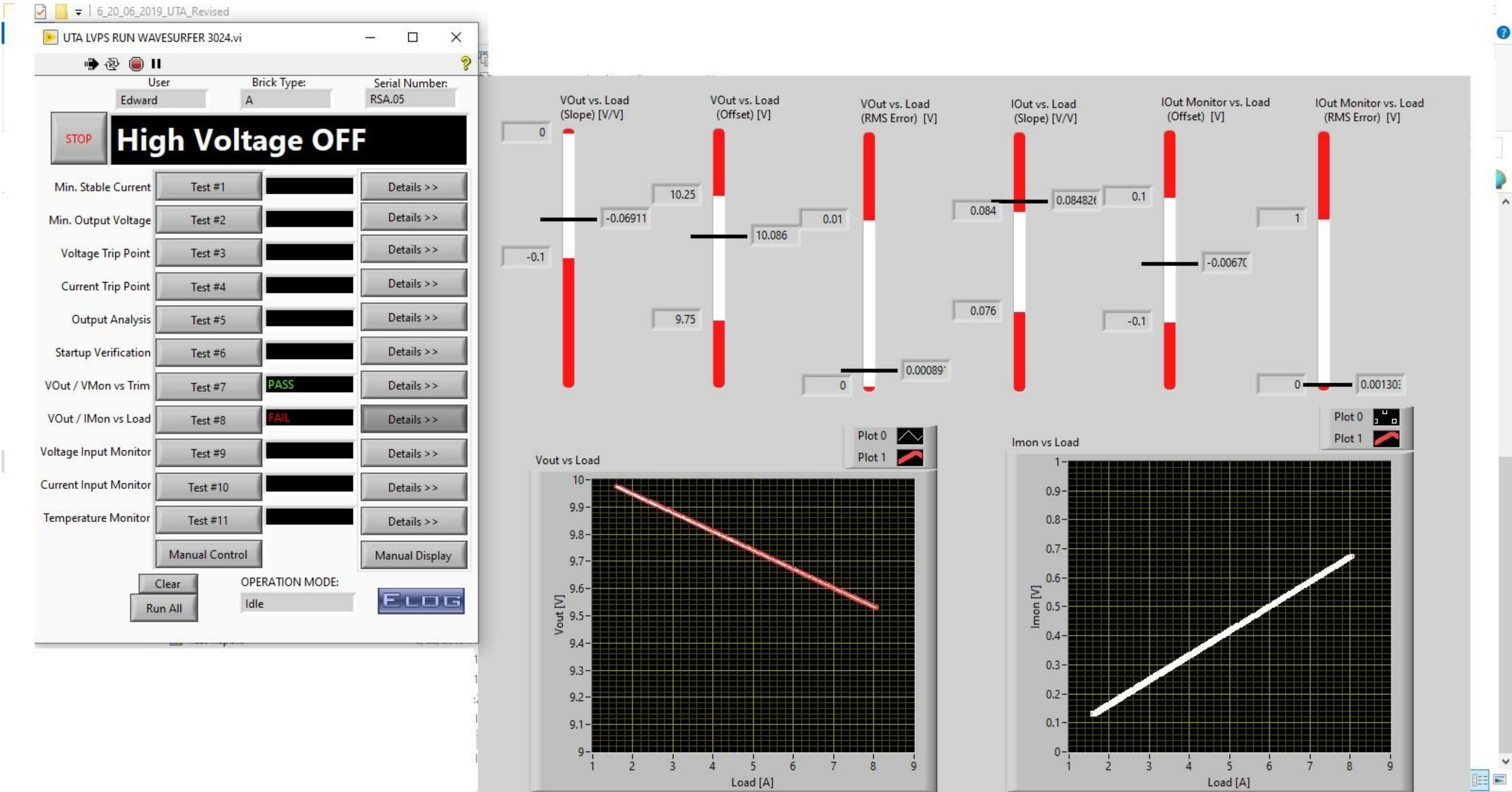
On the RSA brick, the voltage measured on the DAQ for this differential input is ~ 2.3 V representing ~ 10.9 V on the electronic load at nominal load.

How do we measure this differential input with the LEMO connector J1 and VOUT- connected at the oscilloscope BNC connector to chassis ground

Vout / Imon vs Load

Output Voltage vs Load

The changes of the output voltage and current monitor signal are plotted vs load current.



Input Voltage Monitor at Nominal Load

The input voltage monitor signal is measured at the nominal operating point of the brick.