The characterization and functionality of the interface boards used in the burn-in test station for the ATLAS Tile Calorimeter Low Voltage Power Supplies Phase-II upgrade

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Abstract. The Wits Institute of Particle Physics and iThemba LABS are responsible for developing and manufacturing over thousand of the transformer-coupled buck converters, known as bricks, for the Low Voltage Power Supply (LVPS) system. The bricks that pass this test are sent to CERN to be installed in the ATLAS detector in order to turn ON/OFF the front-end electronics. As part of the quality assurance test for these bricks, the burn-in test station is necessary. We describe the Brick Interface (BI) boards on the burn-in station, their operation, and characterize the main aspects of the board, as well as their importance to the entire system.

1. Introduction

The start of the operation of High Luminosity Large Hadronic Collider (HL-LHC) [1] is planned for 2026 with a foreseen integrated luminosity of 4000 fb^{-1}. The ATLAS Tile Calorimeter also known as TileCal [2] is a sampling calorimeter which forms the central region of the Hadronic calorimeter of the ATLAS experiments [1]. TileCal is responsible for the measurement of jet and missing transverse energies, jet-substructure and triggering (including muon information). An individual module (see figure 1) consists of alternating steel (absorber) tiles and plastic scintilators (active medium) tiles and a Super Drawer (SD) which houses the front-end (FE) electronics as well as Photo-Multiplier Tubes (PMTs). When Particles pass through and interact with active tile, it produce light. This light is then transmitted to PMTs located in SDs via wavelength shifting fibers. TileCal must be upgraded to maintain high performance in the new HL-LHC environment. There is a widespread of upgrades on the TileCal, however in this article we will focus on the Low-Voltage (LV) system.

2. LVPS bricks

A brick in figure 2 is a transformer-coupled buck converter, it functions to step down 200 VDC to 10 VDC, which is then distributed to the FE electronics [1]. With its twin transistor forward converter [4], the LT1681 controller chip is at the heart of its design. The chip can switch frequencies up to 300 kHz. The LT1681 controls the switching of the primary side by providing a clock signal to the Field Effect Transformer (FET) drivers. When the FETs conduct, current flows through the primary windings

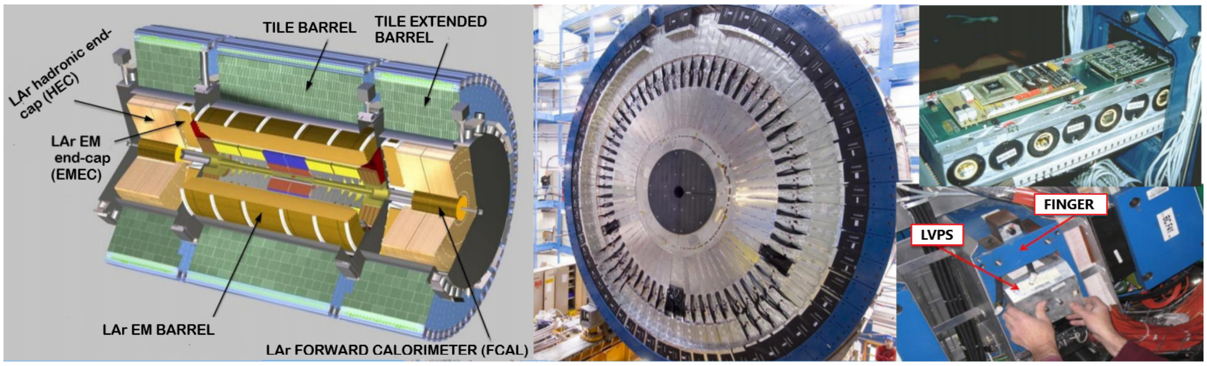

Figure 1: Shows the cross sectional view of the inner barrel (left), modules (middle), electronic drawer and the LVPS system (right) [3].

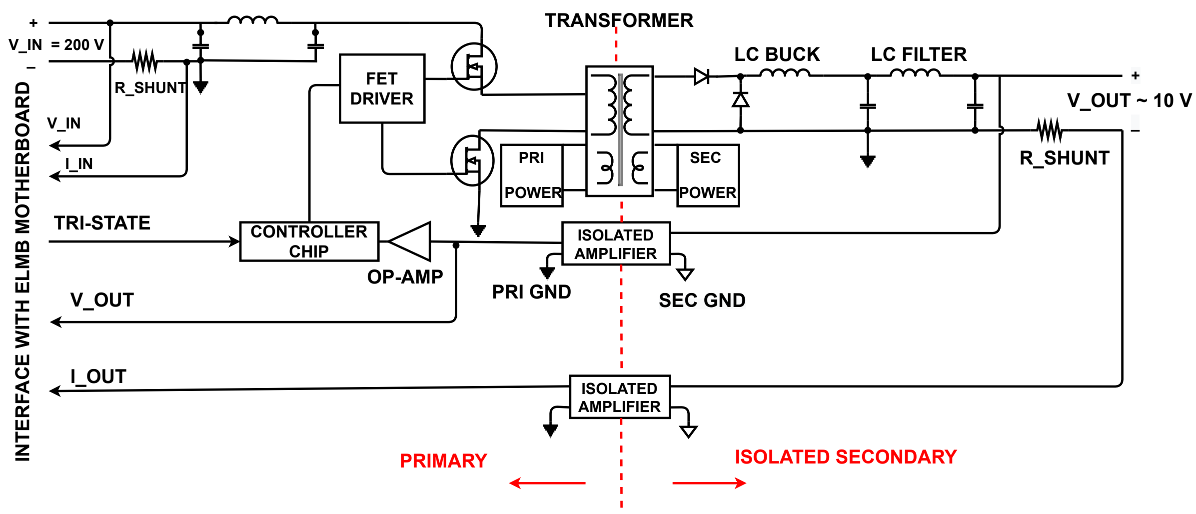

Figure 2: Functional block diagram of the LVPS brick V 8.4.2 produced in RSA [4].

of the transformer, sending energy to the secondary windings. On the output side, an additional inductor-capacitor stage for noise filtering is incorporated when the buck converter is used on the secondary side. The brick includes a built-in remote control and measures that delivers six analog signals (input/output voltages, input/output currents, and two temperatures) to the Embedded Local Monitoring Board (ELMB) is a plug-on board used in LHC detectors for front-end control and monitoring tasks. It communicates using the CAN field bus protocol and provides analog read-out, digital input/outputs and a serial interface to the hardware it is connected to.

3. Burn-in testing

This is a form of accelerated ageing of electronics components. We use this burn-in testing to improve reliability of the LVPS bricks by trying to stimulate a failure mechanism which the bricks experience when they are on normal operation within the TileCal. We use elevated temperature and load to facilitate accelerated ageing. A hardware test station is developed for that purpose. The burn-in electronics, which

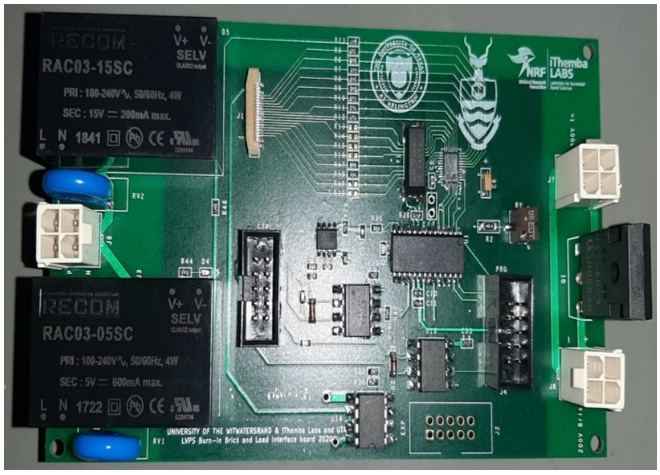

Figure 3: BI board prototype for burn-in station.

include a Main board, eight BI boards, two Dummy load boards, and two Load interface boards, with the focus being on the BI boards. Finally, LabVIEW control programme is used to handle the electronics, high voltage power supply, and data monitoring. The BI communicates with each brick to deliver enable and start-up orders, as well as monitor and read all of the measured analog signals, including as voltages, current, and temperature. The other functionality is to receive 200 V from the power supply and deliver it to the bricks; it acts as a switch for the high voltage power supply. We also have a Universal Asynchronous Receiver-Transmitter (UART) interface with the main board and we have a programmable microcontroller on this board with the same dedicated connector as the main board. Furthermore, the board's local power is provided by AC/DC modules and is used within the board.

4. Simulation and Validation of the BI boards

Programming of PIC16F883 for BI boards: The microcontroller (MCU) PIC16F883 plays a vital role whereby it takes signals received from board mounted Analogical/Digital Converter (ADC) chip and transmits the data to main board. The PIC also received digital communication for the Main boards and by extension the LabVIEW control software. This communication allows for the control of the aforementioned functions of the Brick interface boards. It does this by interpreting data it receives from its Input/Output (I/O) peripherals using its central processor. The BI boards provides the control and data acquisition of a brick and its automated process by the LabVIEW control programme. The temporary information that the microcontroller receives is stored in its data memory, where the processor accesses it, uses instructions stored in its program memory to decipher and apply the incoming data. It then uses its I/O peripherals to communicate and execute the appropriate action. To program an MCU, you'll need multiple software packages, including MPLAB X. An Integrated Development Environment (IDE) is used for writing and configuring code. It works in tandem with the Custom Computer Services (CCS) software compiler, which constructs and compiles the code into a Hexadecimal (HEX) source file. The HEX file contains

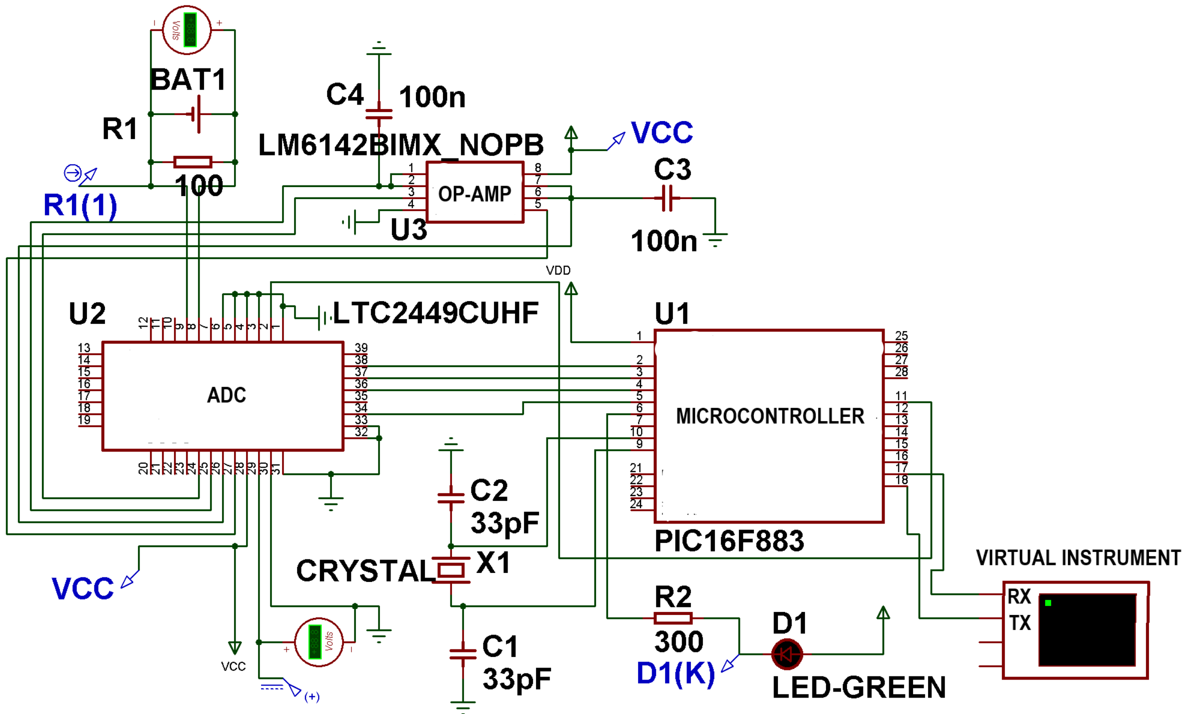

Figure 4: Proteus diagram for the BI boards [6].

settings, configuration information and other data. The MCU only recognises the hex file as a machine code, whereby it carries commands to/from other components. Once the hex file is generated, it is then flashed onto PIC16f883 MCU using the MPLAB X Integrated Programming Environment and PICKIT 4, which allows for debugging and programming of the Microchip PIC [5].

The Proteus framework [6], is used for design, simulation and debugging of a firmware circuit. We used this framework to convert a schematic of the BI board to functional diagram whereby a simulation was carried out to debug the circuits connections. This process is important as it helps in resolving issues that arises on the Printed Circuit Board (PCB) before it is populated. The simulation is also used to check the signal flow and functionality of the PIC as it is the main component on the PCB. In figure 4 we show a simulation of the BI board, whereby I/O peripherals lines of the MCU were checked to observe whether they received or transmitted data.

Validation of BI boards: After the population of the BI PCBs we also perform test on the actual firmware to validate it and draw a correlation as to what was observed on the Proteus simulations. The American Standard Code For Information Interchange (ASCII) characters shown in table 1, are used to request signals from a particular channel of interest. We use the circuit in figure 4 and table 1 and send an arbitrary values to emulate signals that would come from the bricks, a similar test would be carried out on the actual firmware. Before being read and processed by the MCU, the outputs are eventually transformed to digital form. Each sample is assigned a digital value by the ADC, which samples the analog waveform at consistent time intervals. The digital value appears in a binary coded format on the converter's output, which is subsequently

Table 1: ASCII characters sent to ADC to check functionality of each channels

ASCII characters	Function	ADC Channels
1	Brick 15V on	CH0-CH1
2	Brick 15V off	CH2-CH3
3	Brick 200V on	CH4-CH5
4	Brick 200 off	CH6-CH7
g	Read brick input current	CH8-CH9
i	Read brick output current	CH15-CH16
t	Read brick input voltage	CH0-CH1
p	Read brick output voltage	CH2-CH3
e	Read brick temp 1	Ch4-CH5
f	Read brick temp 2	CH6-Ch7
q	Read back address	CH8-CH9

read and processed by the MCU. The terminal program sends out ASCII data in UART format. When you type out a character, the ASCII equivalent is transmitted. The characters are transmitted according to the rate at which you type them. They are not sent at fixed intervals. The ADC, which is at the heart of this BI board, receives and translates all behavioural parameters including voltages, current, and temperature so that the MCU can read and distribute them.

The PC LabVIEW [7] software communicates with all eleven microprocessors in the burn-in station through a single UART layer link passed over a USB bus. UART communication is suitable for embedded system to PC-based microprocessor communications [8]. A Future Technology Devices International (FTDI) integrated circuit is a USB to UART interface used to connect main board with a computer. Only the Main Board physically communicates directly with the PC, and communicates itself directly to every other interface board. Its primary function is to multiplex between the PC and the ten other interface boards. This way, the LabView software on the PC communicates with only one microprocessor at a time. Each interface board for the brick and load contains a 16 bit PIC 16F883 microcontroller.The BI boards provides control and data acquisition of bricks through automated process executed by the LabVIEW control programme. The execution flow diagram shown on figure 5 indicates how the program carries out the tasks as per the users requests, when they're using the GUI of the LabVIEW control programme. The programme enables the user to control and monitor the entire process of the burn-in and record all the information regarding the behaviour of the LVPS bricks. Currently, we are improving the design, structure, and implementation of the LabVIEW control, while preserving its functionality.

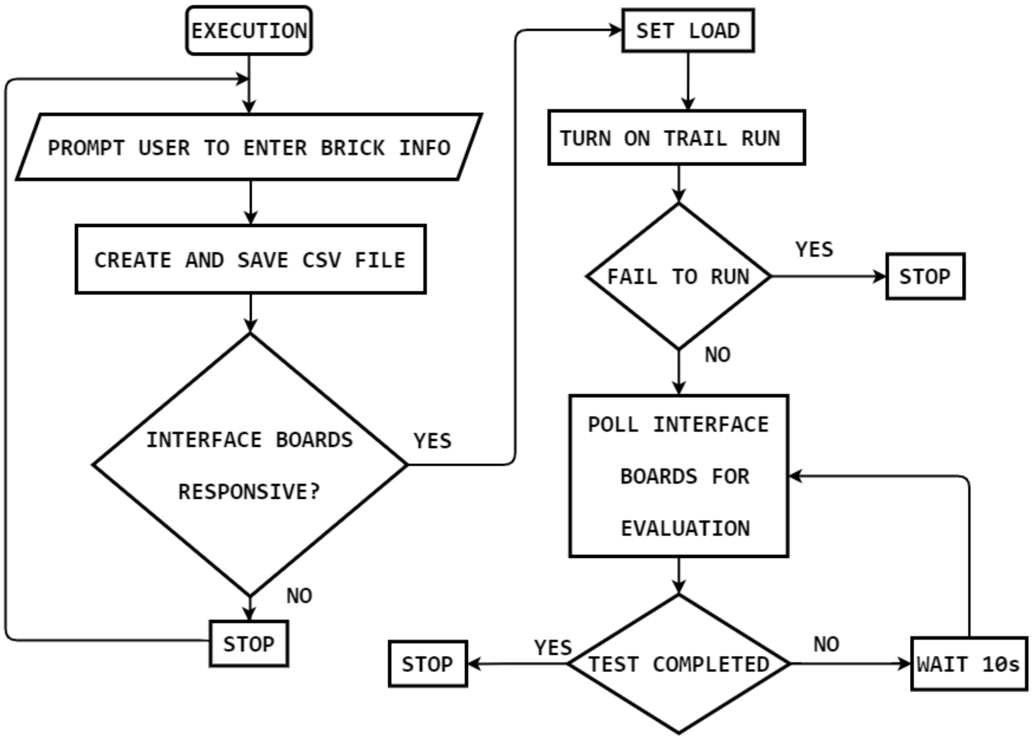

Figure 5: LabView execution flow diagram [9].

5. Summary

The Wits Institute of Particle Physics and iThemba LABS are entrusted with developing and manufacturing over 1000 LVPS bricks for the ATLAS Tile Calorimeter, which will power the detector's front-end electronics during Run 3. Testing mechanisms are necessary for quality assurance to ensure that the design, construction, and production techniques of the bricks are reliable before they are transported to CERN. The burn-in is currently being finalized, with all the boards undergoing functionality testing as well as a review of how they interact with the LabVIEW control programme. An extensive study will be conducted to see how the findings from simulations correlate with the physical firmware outcomes.

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