

Programming the load readout board micro-controllers used in the development of a Burn-In test bench for the ATLAS TileCal Phase-II Upgrade

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Abstract. The University of the Witwatersrand will be producing over 1024 Low Voltage Power Supplies (LVPS) "Bricks" to power the on-detector electronics of the Tile Calorimeter (TileCal) of the ATLAS detector in preparation for the Phase-II upgrade. A brick is a DC/DC converter. The ATLAS Phase II upgrade will increase the instantaneous luminosity of the Large Hadron Collider (LHC) by at least a factor of five. Burn-in type test stations are currently being developed in the Wits high-throughput electronics laboratory for testing the Bricks. Burn-in test station is made up of various Printed Circuit Board (PCBs) with different functions. Each PCB contains a PIC16F883 microcontroller which must be programmed in order for the PCBs to perform their respective functions. The burn-in test station setup consists of a Load readout/interface board used to read and control/adjust parameters of four channels of the dummy load board. This paper discusses how different commands for each PIC microcontroller are written and used to shift bits into the register of the Digital to Analog converter (DAC) contained on the dummy load to control the current and voltage load. A hexadecimal (hex) source file is generated and used by programmable logic devices which provides general information of the configured functions.

1. Introduction

The LHC is a high energy particle accelerator. ATLAS (A Toroidal LHC ApparatuS) as shown in figure 1 is a general purpose detector designed for probing proton-proton (pp) collisions, it is sensitive to a wide range of signatures left by particles. The ATLAS detector is scheduled for an upgrade during the long shutdown between the year 2025 and 2027 in anticipation of the LHC Phase-II upgrade. The High Luminosity LHC (HL-LHC) project will increase the instantaneous luminosity by at least a factor of five compared to the nominal luminosity of $10^{34} \text{ cm}^{-2} \text{ s}^{-1}$ [1].

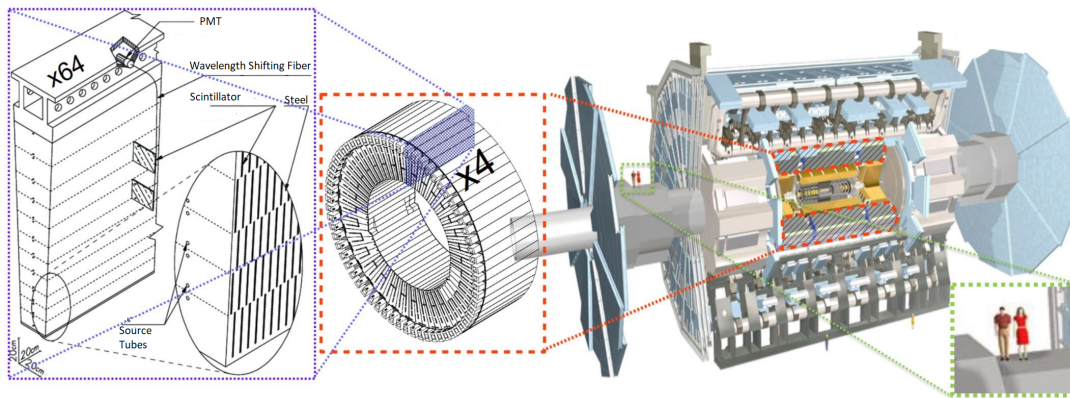


Figure 1. The ATLAS detector [2].

The Tile Calorimeter (TileCal) of the ATLAS detector is the central region of the detector [3]. TileCal is a sampling detector constructed of steel and plastic scintillator plates consisting of 256 wedge shaped modules arranged around the beam axis. The scintillating tiles are placed in the plane perpendicular to the colliding beams and are radially staggered in depth, this is illustrated in figure 1. It consists of 500000 scintillator tiles and TileCal barrels [3]. The TileCal barrels are segmented azimuthally into 64 modules, each serviced by electronics housed in a water-cooled "drawer" at the outer radius of the module. Power is supplied to the drawers by the "finger" low-voltage power supplies (LVPS) located at the outer end of each drawer [3].

2. Low Voltage Power Supply (LVPS) Brick

The LVPS Brick form part of the electronics for the TileCal. They are positioned inside of an electronics drawer. These "Bricks" are DC/DC converters. They convert a 200 VDC input to 10 VDC output required by the front-end electronics of a TileCal module [4]. The switching frequency of the brick is 300 kHz. The brick receives an Enable signal and a start-up pulse from Embedded Local Monitor Board motherboard. The start-up pulse provides temporary power to the control circuits of the brick to power it on [4]. Each brick will be tested using specific procedures and it must pass different criteria. One of the procedures used to test the Bricks is the Burn-in procedure.

3. Burn-In test station

The University of the Witwatersrand is currently developing two Burn-In test stations. Burn-In test station is used to perform endurance type test on the LVPS brick to detect early failures on the components of the brick, thus improving the reliability of these LVPS Bricks. In the burn-in procedure, the LVPS bricks are subjected to high load and elevated temperature. In this environment we expect the operational life of the Brick to be reduced. This allow components to fail immediately within the Burn-in station so that the failed components can be replaced or repaired. The Burn-in test station is made up of a programmable high voltage power supply (200 V), chassis, cooling system, LabView control program, PC and custom built PCBs (Mainboard, Dummy load boards, Brick interface and load interface boards). Figure 2 shows the connections between the different PCBs of the burn-in test station and the high voltage power supply. These proceedings concentrate on programming the load readout board Peripheral Interface Controller (PIC) microcontrollers. This board also consists of an Analog to Digital Converter (ADC).

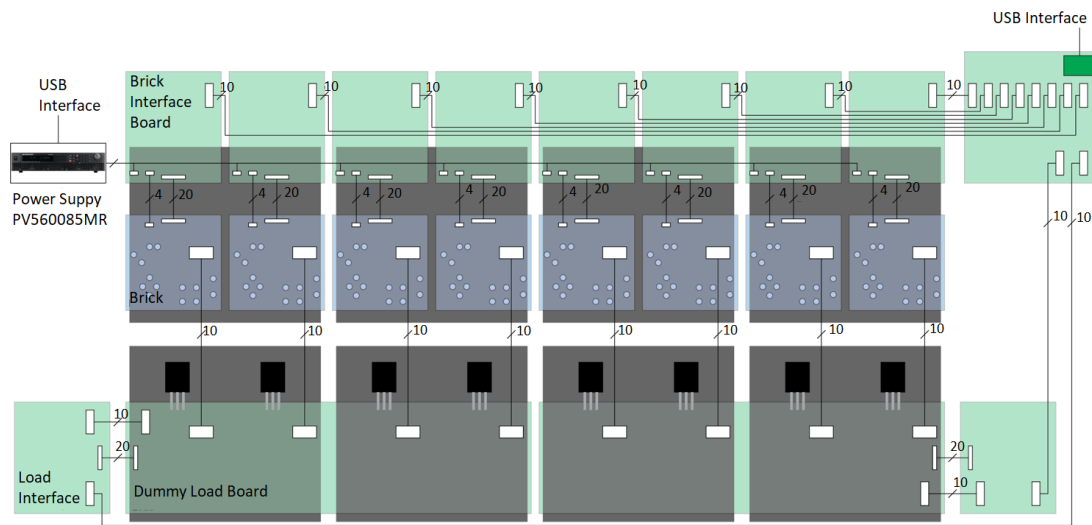


Figure 2. Burn-In test station interconnection block diagram [5]

3.1. Load interface board

The Load interface board communicates with two PCBs, the mainboard and the electronic load. This connection is shown in figure 2 using a block diagram. The electronic load and load interface PCBs are shown in figure 3. The load interface reads the brick differential voltages and currents from the four channels of the electronic load. These values are read as analog signals and a 10 bit 16-channel ADC is used to convert this signal into digital format. A PIC16F883 microcontroller processes this data from the ADC. This information is then passed into the mainboard which acts as a multiplexer. The mainboard is connected to the PC using a high-speed USB 2.0 interface. In order for PCBs to perform their respective functions the PIC microcontroller must be programmed to give the commands for each PCB.

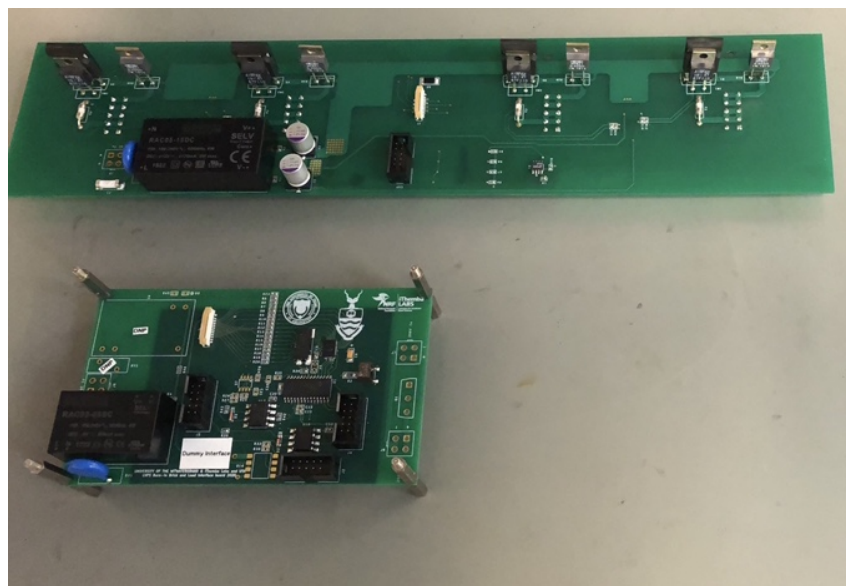


Figure 3. Dummy load (top) and load interface (bottom).

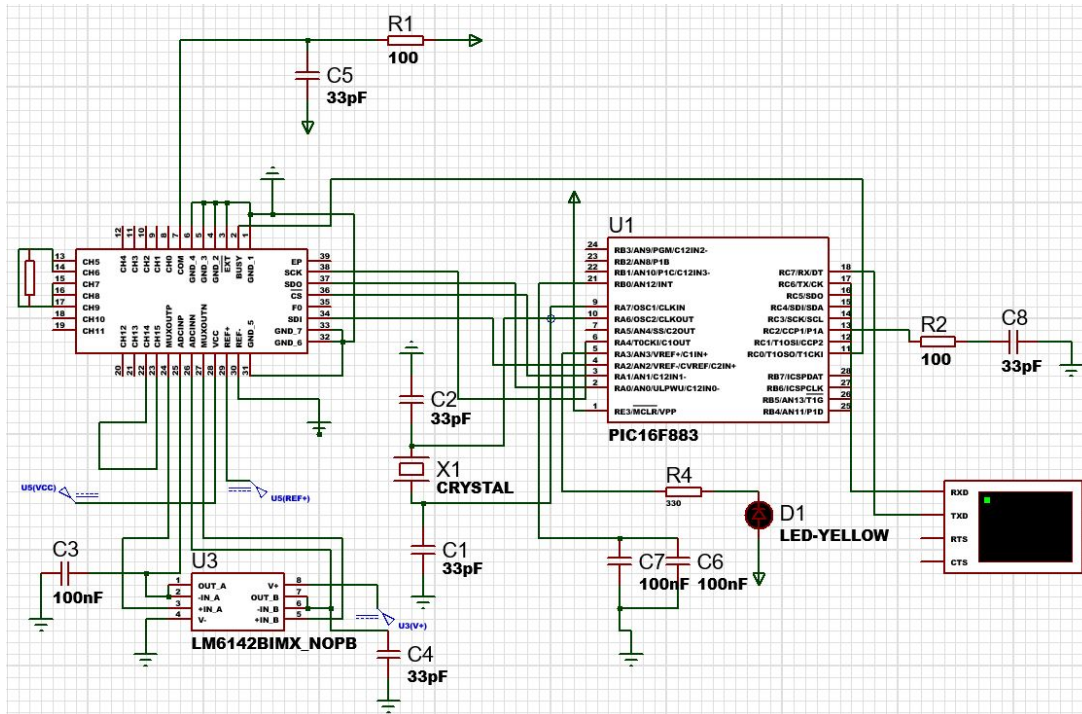


Figure 4. Load interface circuit designed in Proteus for the simulation of the PIC C microcontroller firmware.

3.2. Proteus Simulation

The Proteus software is used for designing, drawing and simulation of electronic circuits. It is beneficial to run simulations of circuits in proteus before you make them practically. One of these benefits is that there is no possibility of burning or damaging of any of the electronic components. Our firmware is compiled in MPLABX IDE using a CCS compiler. A hexadecimal (hex) format source file is generated when compiling in MPLABX IDE. This file contain machine code, these are the commands used to program the PIC microcontroller. The hex file is used in the simulation of the load interface board in proteus ISIS by uploading this file on the PIC microcontroller component of the circuit. The purpose of this simulation is to confirm that our firmware works efficiently before programming the hardware. It is important to set all the properties of the components to emulate the hardware properties i.e. both the frequency for the PIC16F883 and the crystal oscillator must be set to 16MHz. In our simulation of the interface board PIC C code we use ASCII characters used in the switch statement of the firmware to turn the LED ON and OFF. The ASCII character used for switching on the LED is "h" and "l" is used to switch off the LED. We can also send the ASCII character "q" on the virtual terminal of the proteus software to read back module address, the address should change and be unique for each module 1-63. We also designed the load interface circuit in Proteus to be able to read analog signals i.e the brick differential voltages and currents from the 8-differential channels of the LTC2449 ADC. This is done by sending an analog signal (voltage/current) through the ADC channels and the ADC converts the analog signal into binary information and sends it to the microcontroller. The microcontroller processes this information and displays it as digital information on the virtual terminal.

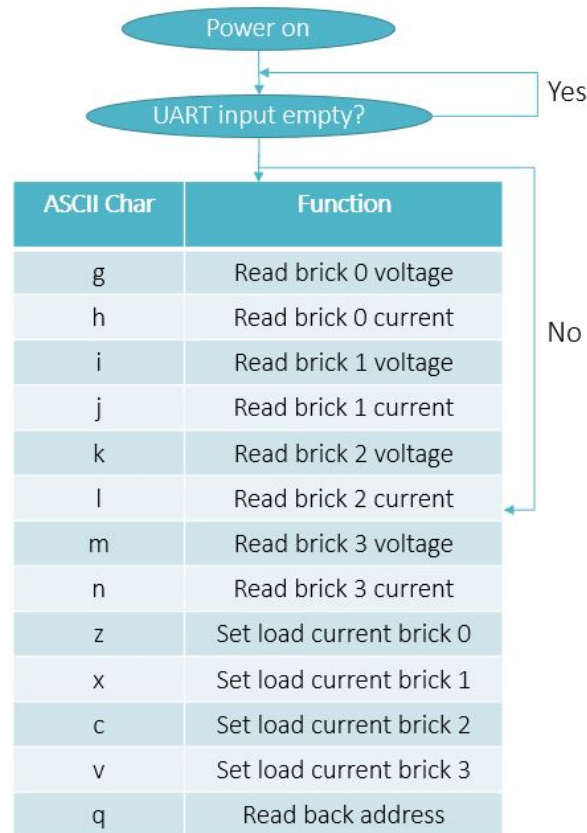


Figure 5. Load interface state machine [2].

Programming the load interface board - To program the PIC16F883 microcontroller PICKit 4 debugger is used. For this setup we require a breadboard, breadboard wires, PICKit 4 debugger, rs232 serial communication cables, PIC16F883 microcontroller and a PC running MPLABX Integrated Programming Environment (IPE) programmer. This MPLABX debugger communicates with the PICKit 4 programmer and it is used for uploading the the hex file containing the commands for the PCBs. When the programming process of the PIC microcontrollers of the PCBs is completed, the boards must be validated using a Real-Time serial capture software. To validate the load interface we can use the ASCII characters just like in the simulation. This means we can send ASCII characters and be able to read the differential voltages and current values from the LTC2449 ADC of the load interface. These are the analog values sampled from the electronic load of the burn-in test station.

In Figure 5 the state machine of the load interface board is shown. The state machine is a structured approach to programming. This is a useful tool for getting a clear and structured code. The state machine of the load interface board works as follows, when the board is turned on the UART input is checked whether it is empty or not. If the UART input is empty nothing happens but if you send the ASCII character, for example character g which is written on the switch statement on the C code, the board will read the brick differential voltage in position 0. All the ASCII character functions are shown on the state machine with their respective functions.

4. Conclusion

Two burn-in test station are currently under development at the University of Witwatersrand. This is in preparation of the pre-production and main production of the Low Voltage Power Supply Bricks. The burn-in test station consists of various PCBs with different functions. These PCBs contains a PIC16F883 microcontroller which must be programmed to allow the boards to perform their respective functions. The PIC C code is written in MPLABX IDE using CCS compiler for microcontrollers. The hex file generated after compiling the C code was used in the simulation of the load interface circuitry. We did this simulation to check whether our firmware works efficiently. The results of the simulation were successful as the firmware works as expected in the Proteus simulation. The PIC16F883 microcontrollers for all the PCBs has been successfully programmed using MPLABX IPE software. The load interface board was validated successfully by sending different ASCII characters using a Real-Time serial communication program and received back the the current and voltage values from each channel of the 16 channels analog to digital converter.

References

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