Project Volta

Automated Variable Load Testing of HV DC Output Boards

ELECOMP Capstone Design Project 2019-2020

Acumentrics is continuing their support of the Program for the 4th consecutive year:
2018-2019: AcuBMS – Battery Management System for Rechargeable Lithium-Based Batteries
2017-2018: AcuPDU – Network Managed Power Distribution Unit for Military Application
2016-2017: AESA – Acumentrics Easy Simple Network Management Protocol Application

Team Acumentrics won 2nd Prize at the 2018 ELECOMP Summit with Project AcuPDU, and 1st Prize at the 2017 ELECOMP Summit with Project AESA

Sponsoring Company:

Acumentrics, Inc.

10 Walpole Park South, Walpole, MA 02081
https://www.acumentrics.com

Company Overview:

Acumentrics, Inc., headquartered in Walpole, Massachusetts, has been a trusted market leader in RUPS™ (rugged AC and DC uninterruptible power supplies) for harsh and combat environments as well as autonomous power and heavy-duty industrial applications, since 1994. Acumentrics products provide clean power conditioning and battery backup when reliability is mission critical. Acumentrics is a preferred supplier of US-made power electronics to many of the world's largest prime defense contractors.

The modern military relies on computers and other sophisticated electronic equipment and relies on Acumentrics' products to keep that equipment online in harsh environments. Electrical variance, surges, spikes, sags, and interruptions can cause communication breakdown and data loss, especially during the rigors of active duty. With new autonomous power systems, these products can range from rack-mounted units to carry-on luggage, backpacks, and even handheld devices.

Some of Acumentrics customers worldwide include General Dynamics, Rockwell, Raytheon, General Atomics, Lockheed Martin Corporation, SAIC, CACI, BAE Systems, OpenHydro, and the United States military including the Coast Guard, Army, Navy, USMC and Air Force.

Acumentrics technology is based on over 25 years of experience in delivering trusted, reliable and rugged backup power solutions to military specifications.

Technical Director:

Brenden Smerbeck (URI College of Engineering Class of 2017)
ELECOMP Capstone Graduate 2017
Software Engineer
bsmerbeck@acumentrics.com
https://brendensmerbeck.com

Brenden Smerbeck has lead Team Acumentrics for two consecutive years, with the team placing second at the 2018 ELECOMP Capstone Summit

Project Motivation:

Acumentrics' UPSs are known for their ability to support a wide array of input sources; while providing clean and reliable output power. The 1U Blade Series UPS has high power density and supports a fault-tolerance N+1 system that allows users to daisy-chain multiple units together. More impressively, this line of UPSs does so in a 1U rack-mount form factor whilst being able to resist EMI, blown precipitation, shock, and vibration across a wide range of temperatures.

Fig 1. The 1U Blade Series Rugged UPS (RUPS)

The 1U Blade, as a result of its size and powerful specifications, is a complex piece of power equipment – composed of over a dozen different printed circuit boards with numerous responsibilities. The end goal is simple: accept any input source, condition and clean the signal, and convert the signal to the required output signal. This is accomplished by intercommunication by controller boards and their connected systems.

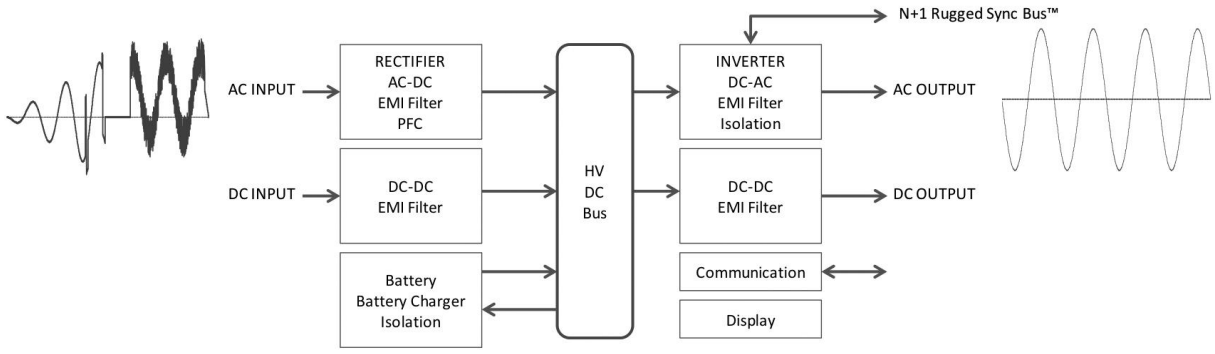

Fig 2. Simplified Block Diagram of Acumentrics` Uninterruptible Power Supplies

One such board, found as part of the block named, "HV DC Bus" in Figure 2, converts a 200 VDC signal to a 28V DC signal before sending such signals for output. It is connected to numerous other systems and is controlled by a central System Controller (SC) board. As such, testing of the board traditionally happens after the UPS is almost completely assembled. If a faulty board is discovered, the system must be disassembled before the board can be replaced and the unit re-tested.

Fig 3. The 1U Blade Series DC/DC Output Board

Anticipated Best Outcome:

The Anticipated Best Outcome (ABO) is a functional prototype system capable of performing an automated load test of the 1U Blade's DC/DC output board. The system must compare the reported characteristics of the board to actual values sensed by the testing system. The system must not rely on any other systems within the 1U Blade and must both visually indicate to the operator the results of the test as well as log the data for analysis.

Project Details:

UPS Block Diagram:

Below is a simplified block diagram of the Uninterruptible Power Supplies produced by Acumentrics. In this diagram, one can see the flow of power from the inputs and through the correction and filtering subsystems, until it meets the charger. The charger serves a dual purpose: stepping down high voltage DC inputs to lower voltages as well as distributing power both to rechargeable batteries and the device's outputs. An additional subsystem governs whether output power is sourced from the input or the rechargeable battery. Output power is either passed through the inverter to be converted to AC or passed directly through as DC power (with proper filtering and EMI protections).

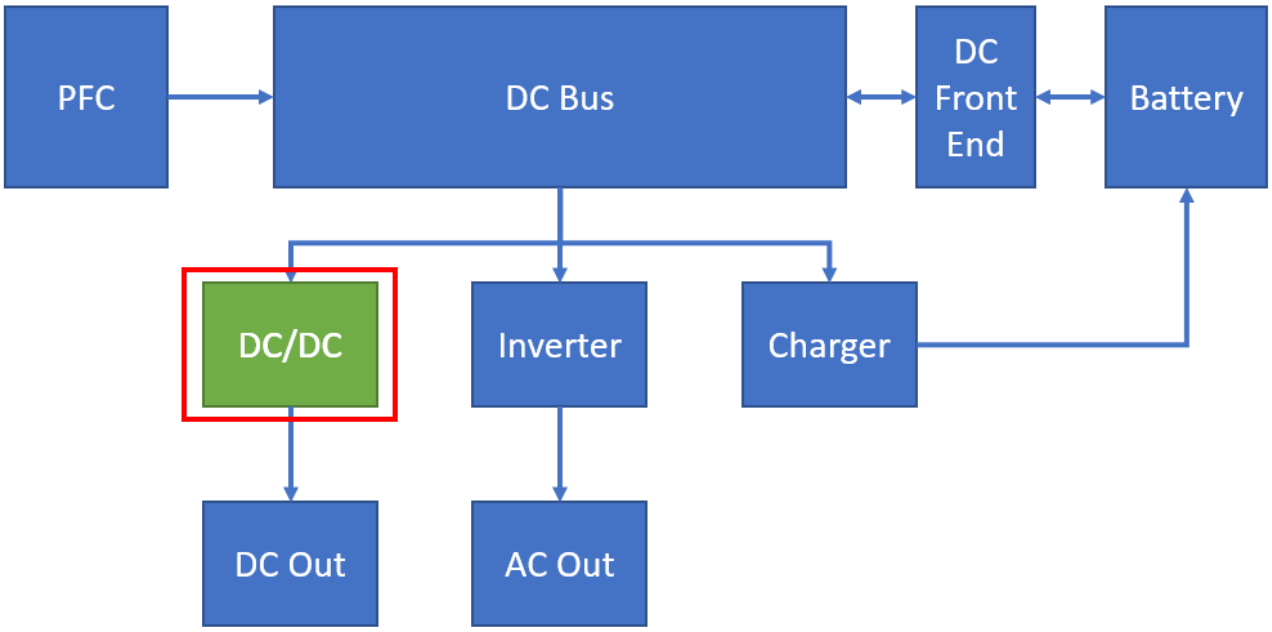

Fig 4. UPS Block Diagram with DC/DC Board Outlined

DC/DC Output Board Description:

The DC output board is composed of two separate boards. The first, and the larger of the two shown below, consists of inputs, a transformer, connection between the main board and the step-down MOSFET board, a microcontroller responsible for pulse-width modulation (PWM) to step down the voltage in an energy efficient manner, outputs, and communication pins to control the actions of the microcontroller.

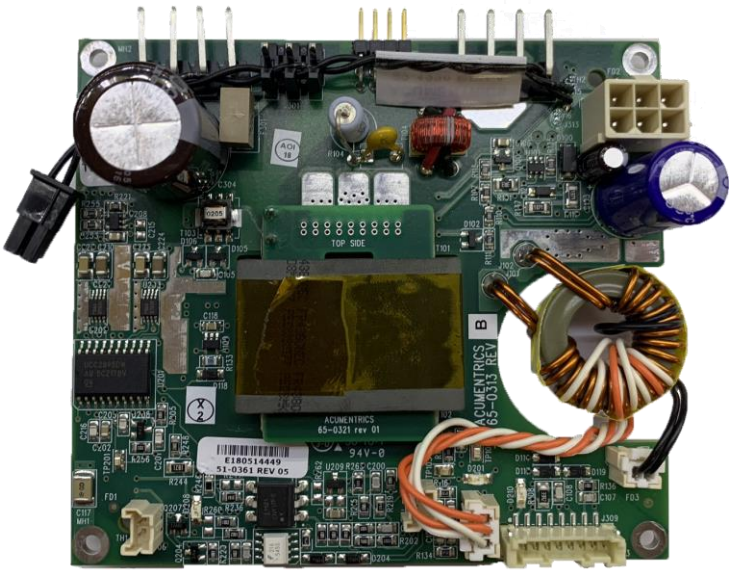

Fig 5. The Main DC/DC Output Board

The second board, consisting primarily of MOSFETS, is responsible for converting input signals to a clean, 28V DC output. This is done using PWM in conjunction with a LC filter. While details of the process will be discussed with the selected team, students may research the topic "DC to DC PWM Converter" to see relevant articles. One such article is supplied below:

https://pdfs.semanticscholar.org/61b3/7bc57824cd10fb29a685571ef89620923a6e.pdf

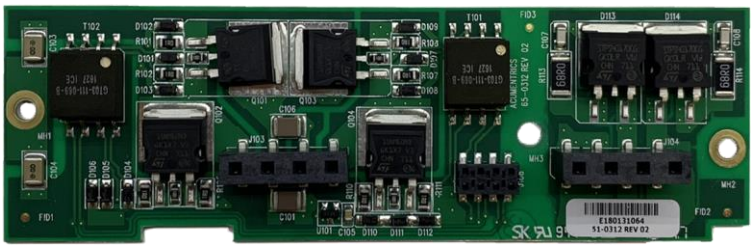

Fig 6. DC/DC Output Converter Stage Board

Description of Problem:

As it currently stands, the only means by which Acumentrics can test the charger board is to almost completely assemble a unit before attaching it to a test fixture. Once connected, an automated suite of tests are run using variables loads, programmable power sources, and communications cables to verify that the board is function to specification. Should the board fail, it is the responsibility of the manufacturing technicians to disassemble the unit, replace the charger board, and re-test the unit. A time-consuming process, this seriously hinders the output performance of the manufacturing department.

It is the goal of Acumentrics, through partnership with ELECOMP Capstone Program, to create a single-function testing fixture capable of verifying the charger boards by themselves. In doing so, boards may be tested upon receival for any defects. Should those defects be found, it would circumvent the time-consuming process of assembly before test and accelerate the manufacturing process of the 1U Blade series UPSs.

Best Outcome – Pass/Fail

For the Anticipated Best Outcome, it is requested that ELECOMP Engineers design a system capable of automatically testing charger boards by themselves. This requires the inclusion of a capable input power supply, a variable load for output, and sensors to monitor both input and output signals of the board. Should the sensed values of the system vary from the optimal characteristics of the board, the operator shall be notified. Additionally, this data shall be logged for later analysis.

Extended Best Outcome – Diagnosis and Point-of-Failure

In the case that the Anticipated Best Outcome is achieved before the end of the academic years, Acumentrics proposes a more difficult goal – point-of-failure analysis of the board itself. To accomplish this, ELECOMP engineers will be required to analyze the circuit schematic of the board and understand the expected characteristics at each node. Once these characteristics are known, the system must be redesigned to support additional sensing at each node. This form of diagnostic is generally accomplished using a “bed-of-nails” or other multi-contact/sensing equipment. This bed-of-nails has numerous points of contact with the board; corresponding to relevant nodes along the circuit. The bed is secured against the board during operation and data is collected during its testing. In doing so, analysis may be extended to the specific nodes and their corresponding components. Note that due to the design of the two boards and their 90-degree angle orientation, the a typical clamp-down bed will not suffice.

Tasks Breakdown:

Electrical Tasks:

- **Pass/Fail**
  - Gain general understanding of high voltage power systems and necessary safety precautions when working with high voltage power systems
  - Gain general understanding of PWM step down controllers
  - Gain understanding of DC/DC output board and its operating characteristics
  - Research and select power source, input sources, and output load to test a working DC output board
  - Learn Acumentrics` current testing procedure for the DC output board
  - Design an automated testing system capable of verifying the performance of the board while also ensuring safety of the operator
  - Select necessary components, and construct the testing system (initial prototype)
  - Validate the design is capable of testing the board for integrity and performance, and that logged data matches end results
  - Construct PCB of designed circuit
    - PCB design and layout may be completed by students or an external party – dependent on complexity of the circuit schematic
  - Test PCB, and create necessary instruction manuals and documents
- **Point of Failure**
  - Identify key nodes of the DC output board as they relate to board and component-level failures
  - Expand sensing capabilities of the system to include all additional nodes
  - Construct a multi-contact/sensing apparatus capable of securely locking the board in place during operation
  - Using the new system, verify that – in addition to a general pass/fail output – the system can identify points of failure or interest to assist with debugging and repair of the board.

Composition of Team:

2 Electrical Engineers (ELE)

Preference will be given to students enrolled in Mike Smith's PCB Design Course as well as students with experience working with high voltage power systems.

Skills Required:

Electrical Engineering Skills Required:

- Analog and Digital Circuit Design
- Digital Signal Processing
- Linear Systems and Signals (e.g. ELE 313+314)

Computer Engineering Skills Requested (NOT REQUIRED):

- Experience using some form of microcontroller for data logging and simple controls
  - e.g. Arduino, Raspberry Pi, BeagleBone, Feather
- Experience using some form of programming language compatible with a microcontroller
  - e.g. Arduino, Python, C (WiringPi)

Anticipated Best Outcome's Impact on Company's Business, and Economic Impact:

A major bottleneck of any product manufacturer is their output rate. Board failures and complicated testing procedures slow down this manufacturing process. By creating tests for individual boards, Acumentrics will be able to produce more UPSs in a shorter time span – allowing us to increase total sales. Additionally, the reduced time spent partially assembling units for testing will reduce manual labor ours of manufacturing technicians; saving the organization money. Should the product succeed, similar methods may be used for other boards within our Uninterruptible Power Supplies. This would have a significant economic impact.

Broader Implications of the Best Outcome on the Company's Industry:

As technology advances to meet the growing needs of businesses, so too must the manufacturing and assembly process. Creating systems such as the one proposed are quintessential in improving the design and assembly process. By understanding the root-causes of failures, assembly-houses can improve upon their own methods and provide more reliable parts and service. This improvement extends from chip manufacturers all the way to the customer – improved reliability means less overall cost, less waste, and better business.