ELECOMP CAPSTONE
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THE UNIVERSITY OF RHODE ISLAND

THINK BIG WE DO℠

Software Development of Thermal & Electrical Model for MRI Gradient Amplifiers

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analogic

Project Motivation

A major business focus for Analogic Corporation is the production of gradient amplifiers (GA), which generate both the current and power required to operate MRI machines. When working with performance-critical machines such as MRIs, unit shutdowns can be highly detrimental in regards to time, resources, and product reliability. Oftentimes, the cause of the shutdown is related to the gradient amplifier power stage - specifically the temperature of the insulated gate bipolar transistor (IGBT) or depletion of the high-voltage capacitor banks. If operators were able to simulate specific input waveforms prior to run-time, and be notified of imminent issues and concerns, the potential for system failure and its negative effects can be eliminated. Thus, having a user-friendly software that can model both the electrical and thermal behaviors of the GA, and ensure completion of the task, is highly desirable. Ultimately, the motivation for this project is to supplement customer demand and reinforce the safety and reliability of the gradient amplifiers.

Anticipated Best Outcome

The Best Anticipated Outcome will manifest itself as a complete deliverable of a fully-functional software package which can accurately model the electrical limitations & thermal behavior of the gradient amplifier systems. The software package should be developed using a secure, freely accessible, versatile programming language that can perform efficient computation, with proper coding practices and maintainability being kept in mind during development. It will contain a user-friendly GUI and be able to perform simulations that will be used to predict failure and shutdown of the MRI gradient amplifier unit. An additional software user manual will be supplied.

Key Accomplishments

Project Foundation

Language Selection: C++ was the selected language of choice for the software project due to the need for high performance and easily encrypted code. C++, being a lower level, compiled language handles both of these requirements elegantly.

GUI Library Selection: Choosing C++ required finding a suitable GUI library to display the application with. The open source Dear ImGui library was selected for being lightweight and simple to integrate into the project, along with providing all the functionalities necessary to implement the requirements of the software.

Electrical Model: Fig. 1 is a high-level flowchart detailing the computational processes involved for the electrical model. The electrical model is accessible by users through the graphical user interface, and accepts user-inputted PWL command signals which are then put through a linear interpolating function. The C++ program performs calculations to determine relevant values such as load current, load voltage, output voltage, and available voltage. Upon completion, it notify users of predicted system failure, time of expected failures, or simulation success.

Thermal Model: The thermal model is also accessible through the graphical user interface, and accepts user-inputted PWL command signals. Using team derived and compiled mathematical equations describing the thermal behavior of the AG700 GA, calculations for cold plate temperature, junction temperature, and overall IGBT junction temperatures are performed. The C++ model outputs expected temperature rise, potential threshold breach, time of simulation failure, or simulation success. A flowchart detailing these computations is shown in Fig.1.

Full Software Integration

Multithreaded I/O: Due to the large file sizes that the program will be taking as user input, an algorithm for handling the input and output data was designed in order to efficiently read and write the information needed and produced by the models. This algorithm uses multithreading to simultaneously read input information, perform computations on that information, and write the results to a file.

Modular Architecture Design: Compatibility with Analogic's other GA products was kept in mind when designing the software architecture, which led to a modular implementation of the gradient amplifier models. The class hierarchy derived from this planning will make maintaining and adding features to the software much simpler in the long run.

Model Integration: Due to the modular nature of the software's simulation implementation, integrating the models of the AG700 involved only slightly modifying the data structures used for multithreading synchronization to account for the fact that the models must adhere to sampling frequency laws.

User Features

Plot & Report Generation: Plotting of both the input data and results from each simulation is handled by a custom-plot implementation made for Dear ImGui. Plotting is handled independently from the simulation computations, leading to a higher performance, quicker-to-completion simulation.

Documentation: Informative documentation and comments have been continually added to the program in order to allow for easy understanding and smooth transition for any future work. In addition, a repository has been created to maintain thorough records of development as well as a user help guide

Project Outcome

The Anticipated Project Outcome was achieved.

An operable software package with the aforementioned capabilities will be delivered to Analogic.

Figures

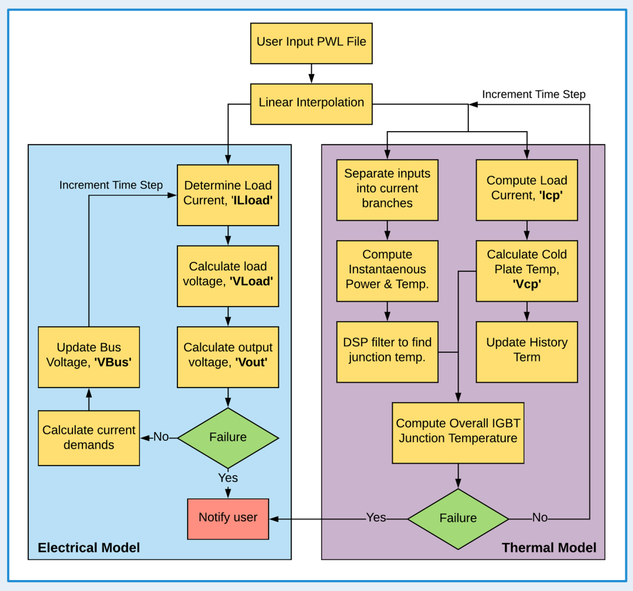

Fig. 1: Flowchart for Electrical and Thermal Model C++ programs

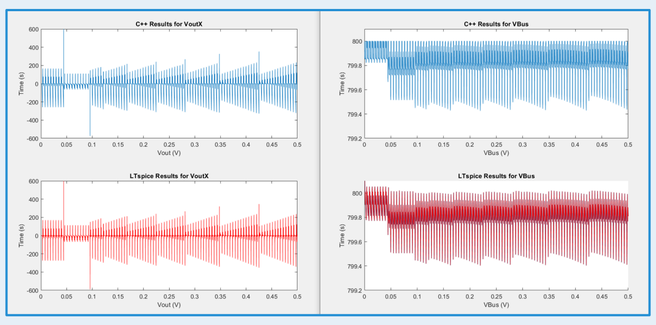

Fig. 2: Verification for Output Voltage (Vout) and Bus Voltage (VBus); C++ vs. LTspice results

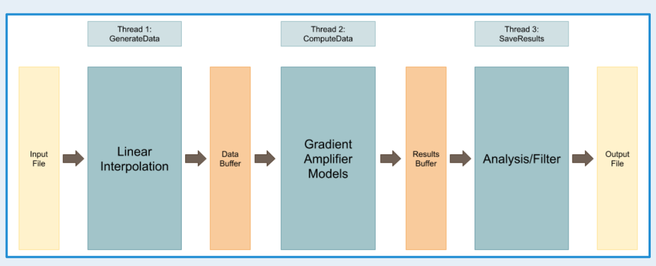

Fig. 3: Multithreaded I/O Design

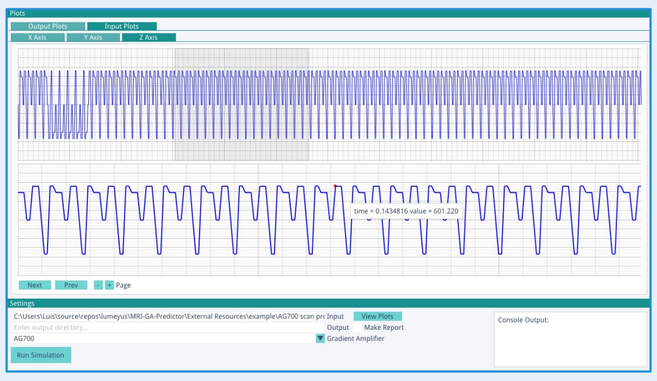

Fig. 4: Main Graphical User Interface of Application

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