Control and performance assessment of a power semiconductor testbench

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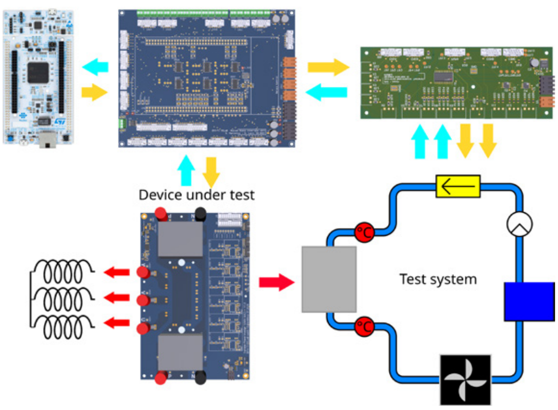
Estimating the efficiency of power semiconductor modules using traditional methods can be inaccurate and unreliable. In this project, a calorimetry-based measurement system is studied and implemented to determine the losses of an IGBT module during stable operation via a controlled hydraulic cooling system.

Introduction

Power semiconductor modules are used in a wide range of applications, from automation to electromobility, robotics, backup power systems, medical devices, hydraulics and pneumatics. Assessing the efficiency of power semiconductor modules is crucial to optimising energy use in any industry. Traditionally, efficiency is measured by calculating the difference between input and output power, using expensive equipment such as power analysers and regenerative AC grid simulators. Despite the high cost, the accuracy of these measurements is typically very low, with a margin of error of +-20%. This project takes a different approach by directly measuring the heat losses generated by the power module.

Losses estimation & result validation

Various efficiency and thermal simulations were carried out to validate the measures obtained and to establish reference points. Two models were developed, one based on MatLab and the other on PLECS. Both models interpolate the data extracted from the module datasheet and calculate the total losses of the semiconductors. In addition, the PLECS model provides a thermal circuit that can be used to calculate and reference junction temperatures.



Overview of the test system and the device under test

Temperature management

The losses of a semiconductor are highly dependent on its junction temperature. To produce an accurate efficiency map, the junction temperature must be both monitored and controlled. The temperature control of these systems consists of a hydraulic circuit that can absorb heat and dissipate it in a controlled manner. The control is done by a predictive algorithm, which is necessary because of the high thermal capacity of the system and the delay caused by the pipes.
The junction temperature cannot be measured directly, but is calculated from the calculated losses and the known internal thermal parameters of the semiconductor module.

Embedded system & real time operation

Apart from the „power electronics" aspect, an important part of the project was the development of the control and measurement software. The software runs on an STM32 chip mounted on a Nucleo board. On the Nucleo board, only internally developed circuits were used. The first board provides the analog and digital interfaces for convenient use of the microcontroller's peripherals. A second board, developed specifically for this project, interfaces the signals with the system's peripherals and components, in particular the flow meter, thermistors, pump and fans.
The software runs in real time, controls the DUT and performs the measures. The data is transmitted live to the PC, which logs it for further analysis.

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