Bringing confidence to power electronics design and testing with the Amantys Data Logger

Monitoring of key operating parameters is a fundamental part of power converter development and laboratory validation, as well as field testing and on-site diagnostics. The Data Logger is a new product developed at Amantys Power Electronics Ltd. that enables accurate, reliable and synchronous measurements and datalogging functions for both the IGBT and diode devices in an operational converter. This article describes the validation of the measurement and logging capabilities and its use in an extensive range of applications.

Introduction

Laboratory test and validation of power converter stacks entails the monitoring of electrical and thermal parameters to ensure the design is fit for purpose, bringing confidence in fulfilling both performance and safety requirements. The Amantys Data Logger has been designed as a flexible platform to support users in getting started quickly with extensive data logging of the converter stack, and is suitable for use in both laboratory and field-testing environments.

The Data Logger is compatible with any gate drive, including third party and Amantys products, and is directly attached to the switching devices with appropriate cables. No control signals are required from the gate drives and it can be used with both Si IGBTs and SiC MOSFETs up to and including 3300 V. The data recorded can be used for stack optimization, converter validation, and as the basis of Junction Temperature (Tj) calculations.

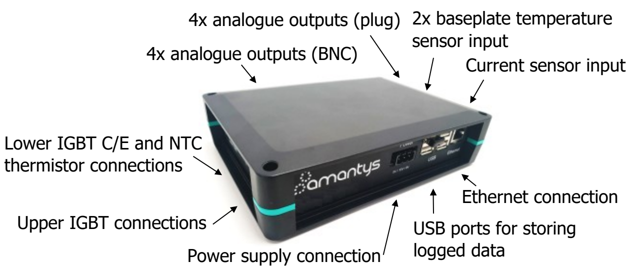

Figure 1: Amantys Data Logger and interfaces.

With compact dimensions of 193 x 143 x 45 mm, it can easily be installed on any laboratory in close proximity to or on a test setup. With suitable precautions against environmental conditions, it may be deployed in the field for on-site diagnostics and long-term monitoring.

Interfaces and Measurements

The Amantys Data Logger enables accurate and synchronous measurements of on-state voltage and current of both IGBT and Diode devices in a half-bridge leg of an operational converter. Additional measurements include the DC link voltage, phase current, PWM timings and external module temperature. An existing Hall-effect current sensor may be used, with signal feeding through the Data Logger on its way to the converter controller, or an extra (dedicated) sensor may be added.

The Data Logger is compatible with a wide range of semiconductor module types and can measure either an internal module NTC thermistor, an external temperature sensor (NTC or PTC), or both. Electrically isolated analogue outputs are available for convenient connection to an oscilloscope or other analogue data channels to facilitate debugging.

Figure 2 shows an example of measurement waveforms taken from a test rig using an open half-bridge module rated at 1700 V/600 A and operating at 500 Vdc, demonstrating the high quality of the on-state voltage and current measurements.

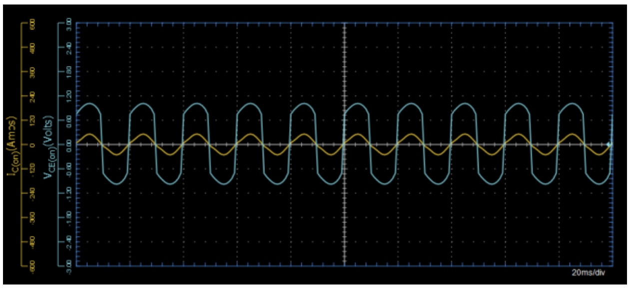

Figure 2: Example of $V_{CE(on)}$ and $I_{C(on)}$ measurement waveforms. For $I_{C(on)}$ 1pu=600 A.

The scope data is recorded and can be analysed and processed independently as shown in Figure 3 to help understand and validate semiconductor devices operation.

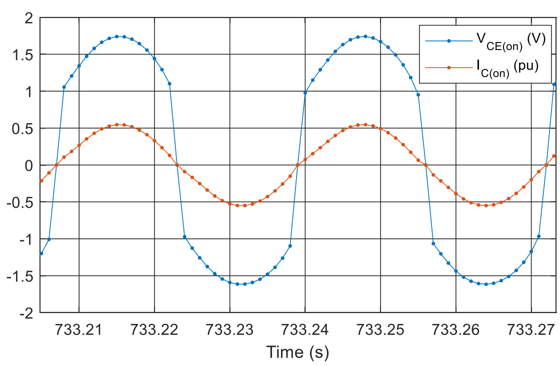

Figure 3: Example of recorded $V_{CE(on)}$ and $I_{C(on)}$ measurement waveforms. For $I_{C(on)}$ 1pu=600 A.

The quality of the Data Logger measurements can be further demonstrated by a scatter plot of the on-state voltage and current, shown in Figure 4 for a given mission profile.

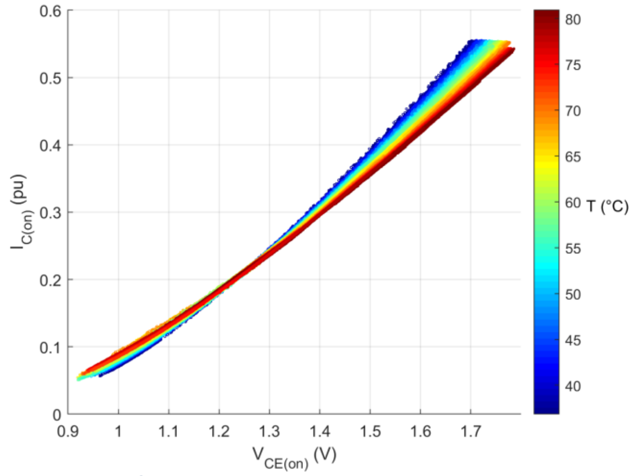

Figure 4: IGBT I-V scatter plot: colour represents the module's NTC thermistor temperature. For $I_{C(on)}$ 1pu=600 A.

These plots allow users to visualize on-state behaviors and check data quality and are available in the Data Logger PC software for each device in the semiconductor module under test, as shown in Figure 5. This rich visualization would be challenging to achieve without the highly accurate and precise measurements supported by a resolution better than 0.5 mV.

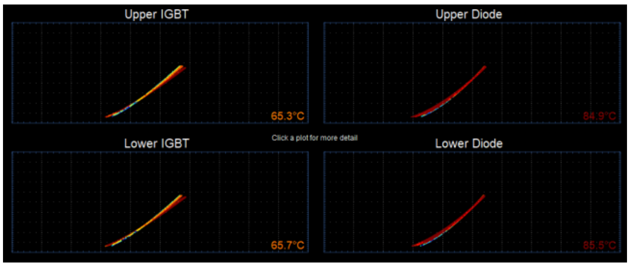

Figure 5: I-V scatter plot for individual devices in a semiconductor module: colour represents the device's temperature

Data Logging

Data logging starts automatically once switching signals are detected, without the need to connect to a PC. This makes the Data Logger a valuable tool for long-term monitoring and data recording, both in a laboratory setting and on-site. All measurements are recorded in .csv format at a 1 ms rate independently of the device switching frequency and are stored on up to four USB memory sticks. Typical storage requirements are approximately 11 GB/day, and by using four 512 GB USB drives logging of 6 months' worth of data is possible.

All measurements may also be streamed over Ethernet using Standard Commands for Programmable Instruments (SCIPI), allowing real-time access to the data, e.g. from the converter controller. The logged data can then be imported into the user's preferred software for further processing and analysis, including for junction temperature estimation.

Detailed Visualisation Software

The Amantys Configurator application software, which runs on a standard Windows PC, can be used in conjunction with the Data Logger to provide data visualisation and simplified configuration functionality such as current sensor measuring resistor and thermistors' parameters.

Figure 6 shows typical operation of the PC software. It allows live monitoring of measurements over Ethernet and has been specifically developed to monitor both short-term signals, e.g. on-state voltage and current waveforms, I-V scatter plots, and long-term signals, e.g. rms or peak current and temperatures. Real-time measurement display windows can be popped-out for convenience and dragged onto the working desktop area to ease monitoring and debugging.

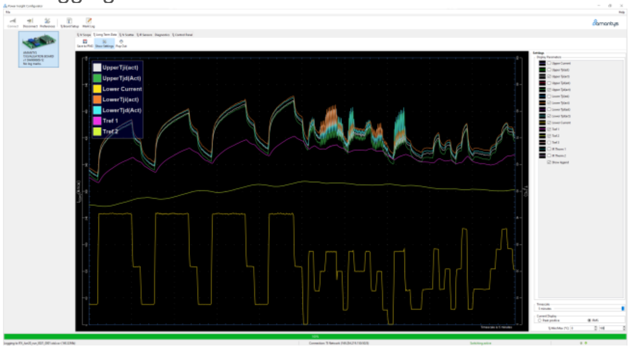

Figure 6: PC software to operate the Data Logger.

Condition Monitoring and Converter Diagnostics

The ability to operate independently of a PC enables the Data Logger to be used not only for converter stack validation and diagnostics, but also on-site deployment; bringing confidence in meeting design and performance requirements.

Semiconductors remain the most fragile components in power converters and unexpected failures have significant economic impact. Thus, timely detection of early wear-out can enable predictive maintenance and contribute to increased availability and revenue.

Since damage-sensitive parameters such as R_{th}, R_{CE} or P_{loss} can be detected through the changes in $V_{CE(on)}$, the long-term monitoring of these parameters can give early indication of both wear-out and abnormal behaviour. This is shown in Figure 7. Accordingly, Amantys technology inherently provides the parameters required for condition monitoring of power semiconductor devices.

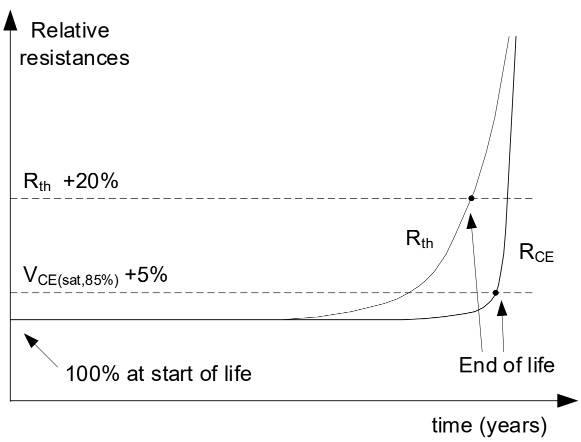

Figure 7: Condition Monitoring of power semiconductor devices though detection of changes in $V_{CE(on)}$.

Junction Temperature (Tj) Estimation

Junction temperature (Tj) estimation is a key tool for power converter design and its knowledge can enable not only significant improvements in converter rating, but also allow operators to benefit from advanced warning of abnormal operation, which is reflected in Tj and/or the electrical characteristics measured. These benefits become more important as converter power densities increase and operating costs have to be reduced.

The on-state voltage drop is the only temperature sensitive electrical parameter (TSEP) that is universal to all power devices, converter switching patterns and gate drive methods [1]. The accurate measurement of both the on-state current and on-state voltage drop provided by the Data Logger enables the user to estimate devices' junction temperature offline, giving confidence in validating converter rating and diagnosing operating issues on any converter application. An example of the accuracy of this method can be observed in Figure 8 where a comparison is presented for the estimated temperature for an IGBT calculated using logged data, and the temperature detected with IR sensors on an open module, showing exceptional closeness.

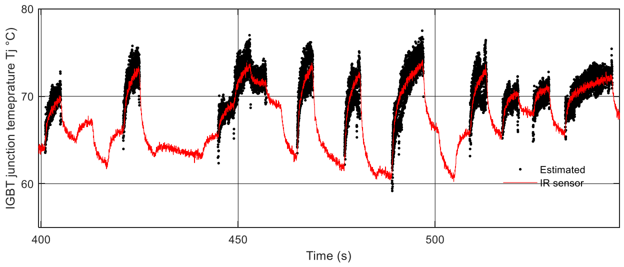

Figure 8: Validation of estimated IGBT junction temperature.

Converter Integration

For pure condition monitoring, Tj estimation or retrofit applications, Amantys has the expertise to design a more compact version of the system to allow integration into production-level converters.

On request, Amantys can work with customers to integrate some functions into a customer application. As an example, using an Amantys gate drive such as the one shown in Figure 9, accurate on-state voltage and other measurements such as a thermistor temperature can be sent effortlessly across the isolation barrier, and made available to the customer converter stack.

Figure 9: Example of Converter Integration flexibility: Amantys Gate Drive.

Conclusions

Powered by accurate synchronized on-state voltage and current measurements, the Amantys Data Logger provides a robust platform for converter stack laboratory development and validation, field deployment and diagnostics, as well as condition monitoring for both the IGBT or MOSFET and diode devices in an operational converter. Its compatibility with both Si, SiC and Hybrid modules associated with its flexible software platform designed for future upgrades and new features makes the Data Logger an essential piece of equipment to anyone who wants to be confident in the abilities of their power electronic converters.

References

[1] N. Baker, M. Liserre, L. Dupont and Y. Avenas, "Improved Reliability of Power Modules: A Review of Online Junction Temperature Measurement Methods," in IEEE Industrial Electronics Magazine, vol. 8, no. 3, pp. 17-27, Sept. 2014, doi: 10.1109/MIE.2014.2312427.