Application Note: IPAN1002

SymCool™ Operation and Driver System

Table of Contents

Introduction

This application note provides an overview of the SymCool™ power module and explains the design of the driver system. It presents a detailed description of the functionalities of the SymCool™ power module Double Pulse Test (DPT) Test System. To operate the SymCool™ power module, the following additional equipment, which is not provided by Ideal Power, is necessary: 24V DC power supply for the driver, external inductor, pulse generator for double pulse test, high voltage power supply, and an oscilloscope.

Hardware System Overview

The hardware system consists of SymCool™ power module, driver board and DPT power board. This section gives an overview of the individual components and illustrates how to connect them and other equipment such as power supply, external inductor, etc. utilized in the testing.

SymCool™ Power Module

SymCool™ is a novel silicon-based bidirectional switch with ultra-low forward voltage drop and low switching losses that can be used in both unidirectional and bidirectional switching applications. Figure 2 shows the SymCool™ power module equivalent circuit and appearance. It consists of four B-TRAN™ dies connected in parallel with eight MOSFETs in a cascode structure. A sample picture of the SymCool™ power module with pin definition is shown in Figure 1 as well. The operating principle of SymCool™ is the same as previously reported B-TRAN™ operation.

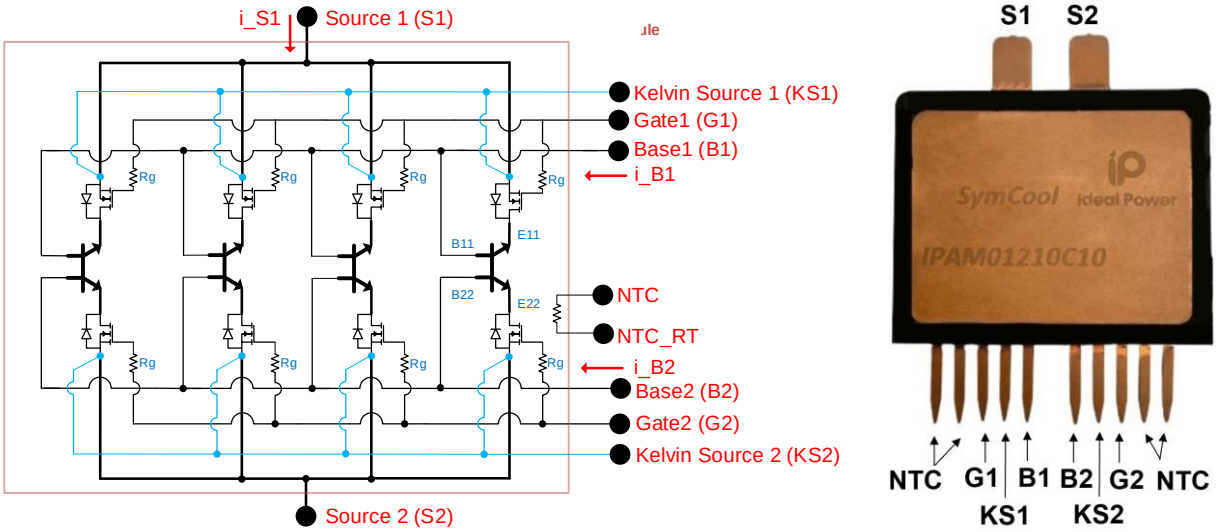
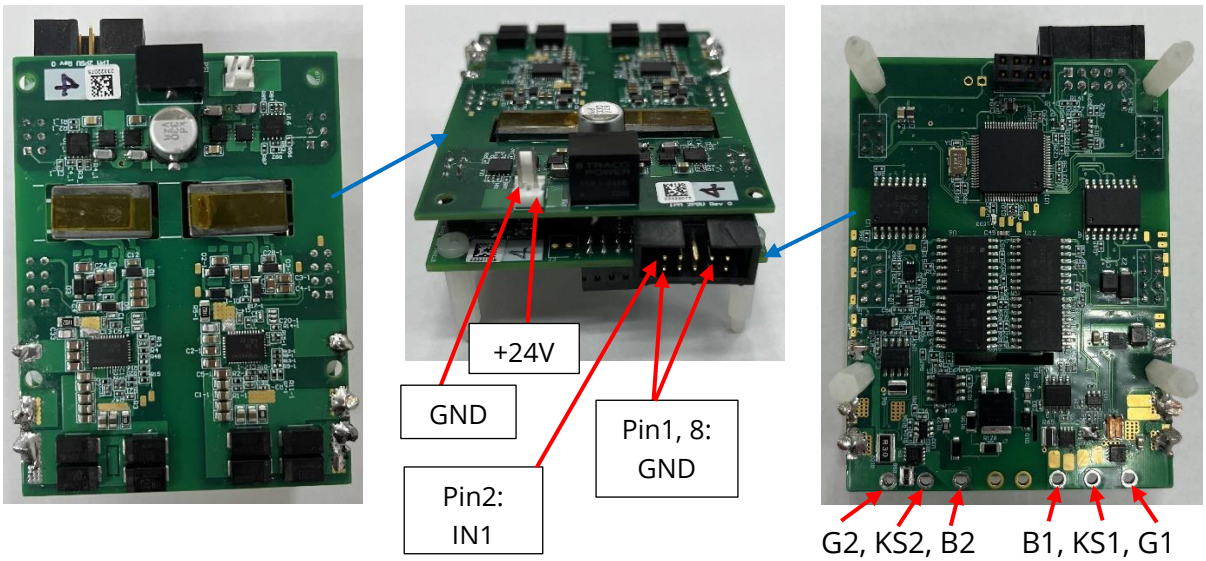


Figure 1 SymCool™ power module equivalent circuit and sample picture with pin definition.

SymCool™ Driver

The SymCool™ driver board is shown in Figure 2. The driver board consists of 2 boards including a Controller board and a Power Supply board as shown in Figure 2.



(a) Power Supply (b) SymCool™ Driver (c) Controller

Figure 2 (b) SymCool™ driver board. The driver board consists of: (a) power supply board and (c) controller board.

DPT Power Board

A DPT system is used to evaluate the SymCool™ power module switching performance. A significant advantage of SymCool™ is its bidirectional switching capability which can be tested using this power board. A SymCool™ DPT power board is shown in Figure 3. The differential probes are required to measure high voltage such as $800V_{DC}$.

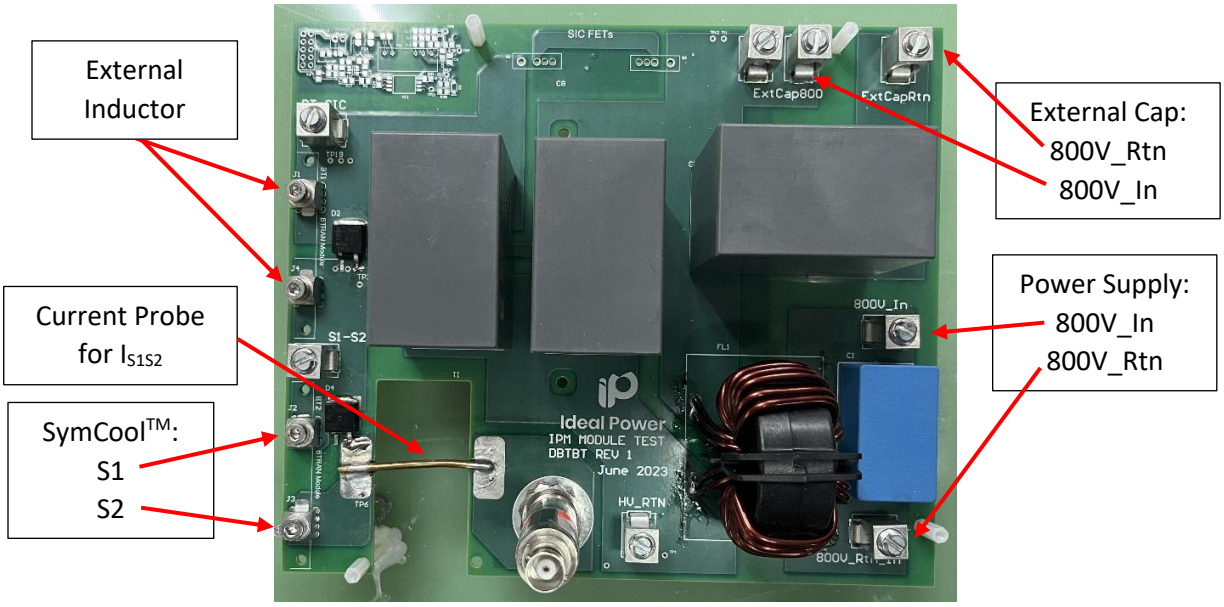


Figure 3 SymCool™ DPT power board.

SymCool™ DPT Test System

The SymCool™ power module DPT Test System consists of a SymCool™ power module, driver board and DPT power board as shown in Figure 4.

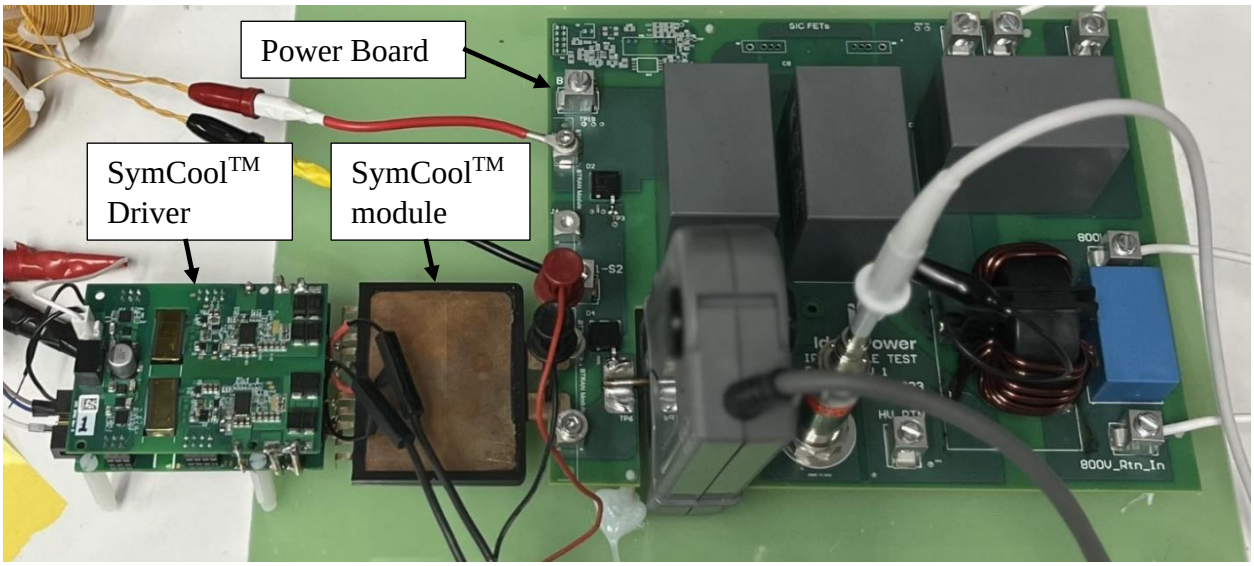


Figure 4 SymCool™ power module DPT Test System.

Other Equipment and Test Setup

The recommended testing equipment includes one multimeter, one signal generator, one high voltage power supply (~1200V), one auxiliary (isolated) DC power supply (for 24VDC), one high voltage differential voltage probe, one oscilloscope with two single-ended voltage probes and two current probes including one Rogowski current probe for I_B.

Connections

First connect the signal generator using a coaxial cable at signal input at the DPT Test System. Connect +24V auxiliary power supply at the 24VDC power input. Set the CC pin in the power supply = 5A and the first readings at this power supply should read 24V and current <0.3A.

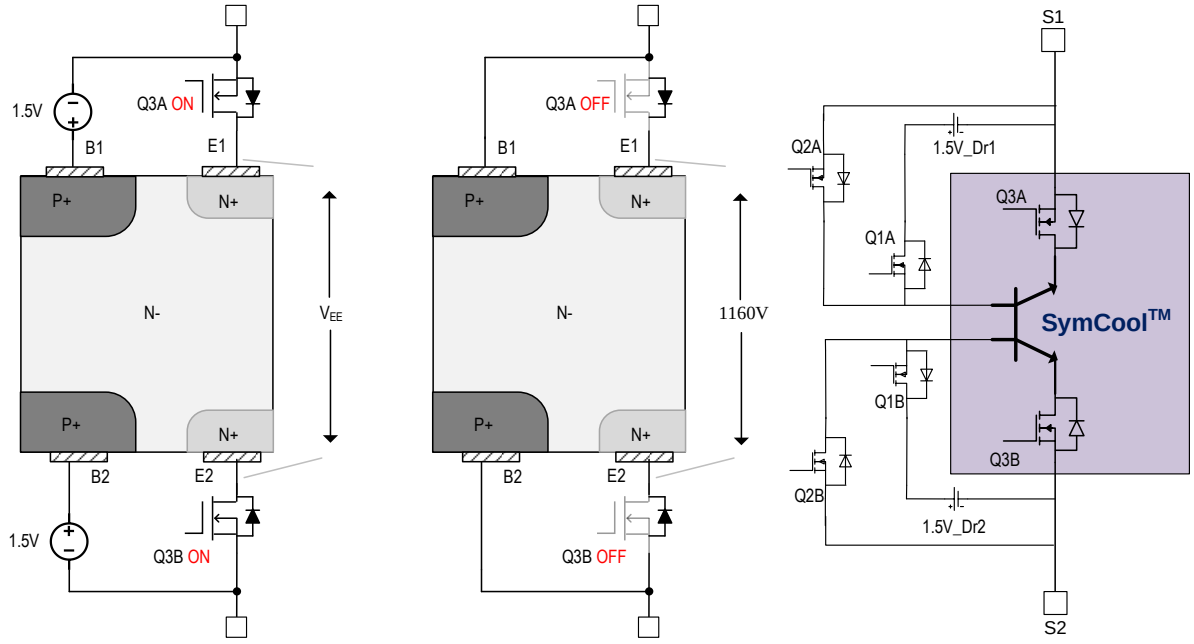
Connect an inductor (around 2mH or a similar value given) to the inductor connection points of the DPT Test System. For inductance value and current rating questions, please consult with Ideal Power for further support. Next, connect the high voltage DC supply at the HV connection points (800V and 800_RTN).

One signal probe is connected to show the control signal on the oscilloscope. A Rogowski coil probe is inserted into the base to sense the base current. Another current probe is used to sense the emitter-emitter current. Connect the high voltage differential probe between two test points.

SymCool™ Power Module Switching Operation

B-TRAN™ is a normally-on device, but SymCool™ is a normally-off device due to internal cascode structures as shown in Figure 5 below. Since SymCool™ contains four B-TRAN™ dies connected in parallel with eight MOSFETs in a cascode structure, for the sake of simplicity only one die will be used to explain the theory.

In Figure 5, the two MOSFETs (Q3A and Q3B) are low voltage (<60V) MOSFETs which have low on-state resistance to keep the total conduction losses low. Both Q3A and Q3B are needed for bidirectional applications. The circuit implementation of this design is shown as well.



(a) On State (b) OFF State (c) Circuit Implementation

Figure 5 SymCool™ Power Module Control Mode.

SymCool™ Turn-On

To turn on the device, both Q1A and Q1B are turned on which allows driving current to flow in the drift region and lowers the resistivity of the device. Q3A and Q3B are then turned on to allow load current to flow between S1 and S2.

SymCool™ Turn-Off

When turning off the device, Q1A and Q1B are first turned off and Q2A and Q2B are turned on. After a small dead time, Q3A and Q3B are turned off, to create pinch-off voltage between B1-E1 and B2-E2 and block current and voltage in both directions.

SymCool™ Power Module Driver Design

The proposed device operation enables bidirectional conduction and blocking without the need for sensing the voltage/current direction. Being a current driven device, the bases B1/B2 are driven by a low voltage, high current supply. This is typically implemented by a buck converter. Q3A and Q3B are low voltage silicon MOSFETs of 60V maximum breakdown voltage or less. Hence, a very low resistance (1-2mΩ) MOSFET can be chosen without significant size and cost impact to keep the overall conduction losses low. Q1A, Q2A, Q1B and Q2B are also low voltage MOSFETs of 20V or less maximum breakdown voltage. Appropriate gate drivers and digital isolators for required isolation can be chosen based on the application.

Figure 6 shows an internal block diagram of the SymCool™ power module driver for bidirectional applications. The SymCool™ power module is shown in the purple box.

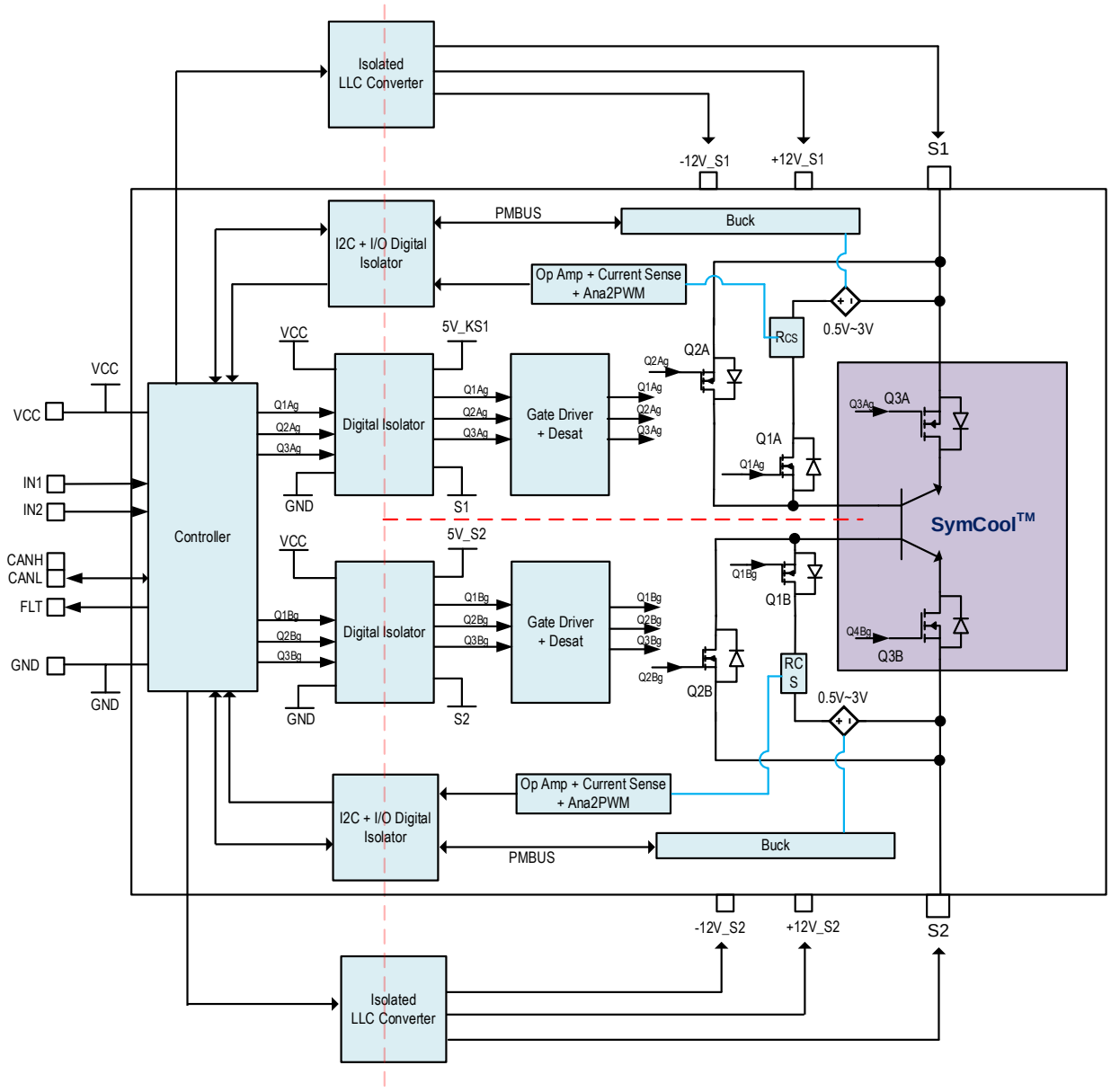


Figure 6 SymCool™ power module driver block diagram.

SymCool™ Driver Logic Control

The logic signals for each FET in the circuit are shown in Figure 7. Q1A/Q2A and Q1B/Q2B are operated as a typical half bridge with a programmed dead time to avoid any shoot-through condition. Q3A and Q3B are turned on/off based on the input

signal and an appropriate delay. A simple DSP/microcontroller can be used to generate such logic signals. Or it may also be implemented in analog by simple AND/NAND gate ICs. With microcontroller/DSP, other functionalities such as current sensing, fault diagnostics and communication such as CAN/LIN can be implemented to optimize the overall system cost.

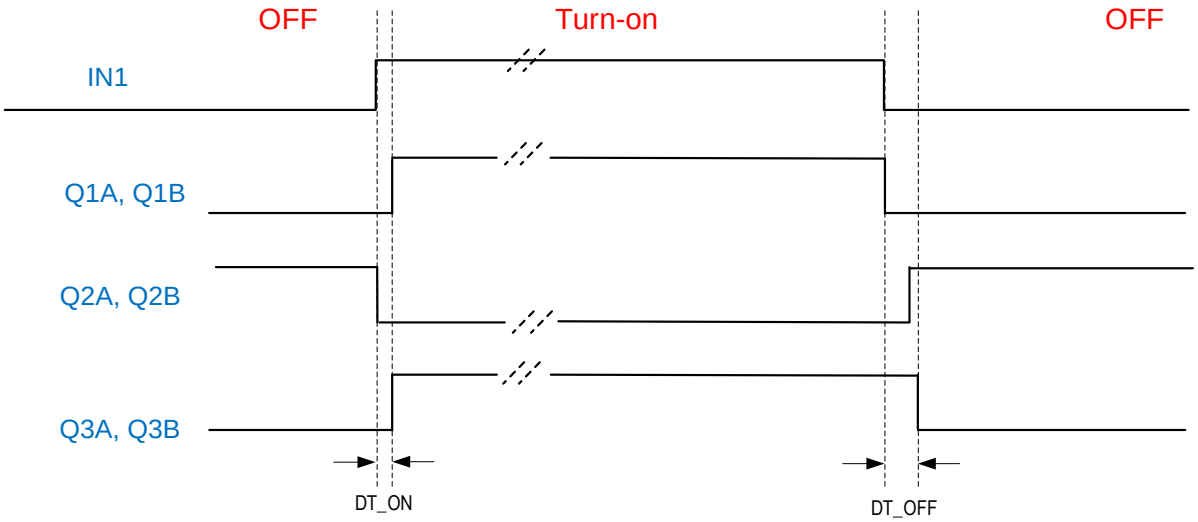


Figure 7 SymCool™ power module driver logic signals.

SymCool™ Power Module Test Results

Figure 8 illustrates the test setup and switching waveforms at 600V 400A for the SymCool™ power module DPT Test System. SymCool™ Driver System is a reference design for switching performance evaluation of SymCool™ power module. With low packaging impedance and ultra-low conduction losses, SymCool™ power module can provide low overall losses and high performance in bidirectional switch applications.

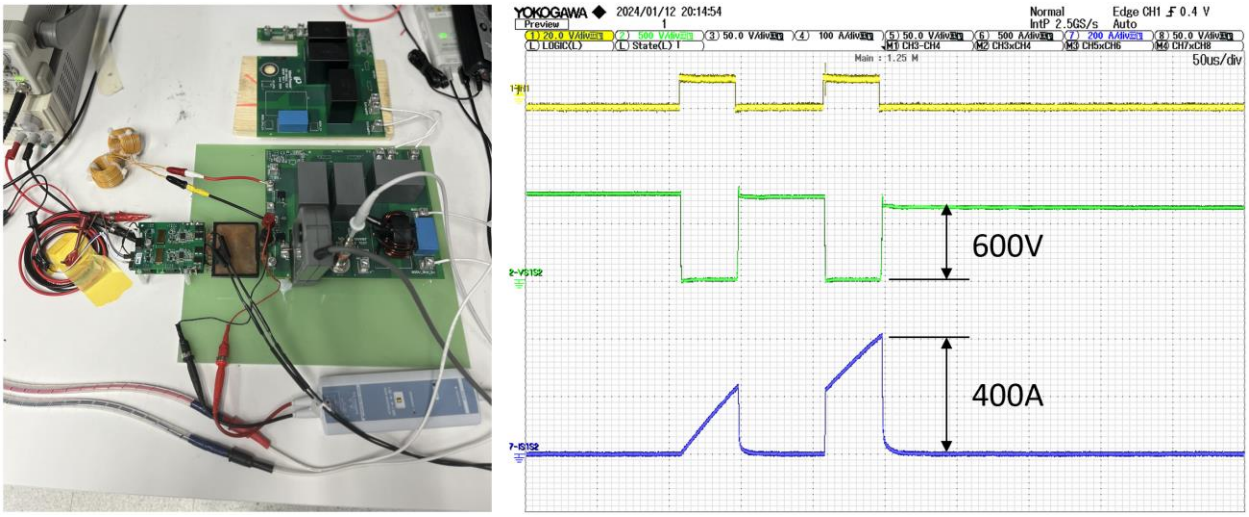


Figure 8 SymCool™ power module test setup and switching waveform at 600V 400A.

Important Notice

The information provided in this document is intended solely as guidance for the implementation of our products and should not be construed as a representation or warranty of specific functionality, condition, or quality of the product. Ideal Power hereby disclaims all warranties, express and implied, including but not limited to warranties of merchantability, fitness for a particular purpose, or non-infringement of third-party intellectual property rights, with respect to the information provided in this document.

The data contained in this document is intended exclusively for individuals with technical expertise. It is the responsibility of the customer's technical departments to:

1. Select the appropriate Ideal Power products for your specific application.
2. Design, validate, and thoroughly test your application.
3. Ensure that your application complies with applicable standards, safety regulations, security requirements, and any other relevant criteria.

Please note that these resources may be subject to change without prior notice. Ideal Power grants you permission to utilize these resources exclusively for the development of applications utilizing Ideal Power products as described in the provided resource. Any reproduction or display of these resources for other purposes is strictly prohibited. No license is extended to any other Ideal Power intellectual property rights or third-party intellectual property rights.

For further information, please contact sales@idealpower.com